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LIFE OF WATT.

James Watt

THE LIFE

OF

JAMES WATT,

G. W. McGiven
Elmira, 1859.

WITH

SELECTIONS FROM HIS CORRESPONDENCE.

BY

JAMES PATRICK MUIRHEAD, M.A.,

AUTHOR OF 'THE ORIGIN AND PROGRESS OF THE MECHANICAL INVENTIONS OF WATT;' 'CORRESPONDENCE ON THE DISCOVERY OF THE COMPOSITION OF WATER,' ETC.

WITH PORTRAITS AND WOODCUTS.

UNIVERSITY OF MICHIGAN
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PREFACE.

The present volume may, it is hoped, supply a want which has long been felt; that, viz., of a full, yet compendious and authentic biography of James Watt. In a recent work,* prepared by the author from the MSS. of the great engineer preserved by his son, as well as from others, of no less value, in the possession of Mr. Boulton, there were comprised, (1.) a Biographical Memoir of Mr. Watt; (2.) a Selection from his Correspondence; and (3.) the Specifications of all of his Patents. The favour with which that work was received by the press and the public is gratefully acknowledged. The long series, however, of large copper-plate engravings of machinery by which it was illustrated,—(thirty-four in number, delineating no fewer than sixty-eight separate figures),—necessarily raised its cost above the means of many who might otherwise have desired to possess it; while the minute descriptions contained in the specifications of patents, and their relative drawings, are of course more desirable for the use of the scientific engineer and the mechanical philosopher, than of the general reader.

The author has now, therefore, ventured to remodel, and to reproduce in a form at once more comprehensive, more convenient, and less costly, the Biographical Memoir above referred to. A few unimportant pages have been omitted;

---

* 'The Origin and Progress of the Mechanical Inventions of James 'Watt.' 3 vols. 8vo. and 4to. London: John Murray, 1854.

many of the most interesting passages from the correspondence of the great engineer have been incorporated; and other large additions, from various sources, have been made,—a considerable portion of the new matter relating to Mr. Watt's family and private history; while the principle has been adhered to, of allowing his inventions and discoveries to be explained, as far as possible, in his own plain, clear, and forcible language.

Of the immense results of those inventions, and their present and future value to the world, it is already difficult to form any adequate conception. But some faint idea of their magnitude may be gathered from such facts as these:—that less than a single century ago, only a few clumsy and imperfect "fire-engines," of the old atmospheric sort, were employed in pumping water out of some widely-scattered coal-pits and mines; that they did their task laboriously, expensively, and badly; that steam was not then applied directly, nor, as then used, was it capable of being applied with advantage, either to Manufactures, to processes in the Useful Arts, to Navigation, to Land Transport, to War, or to Agriculture;—and that now, the united steam power of Great Britain alone, employed in all of those different ways, (every engine having been constructed since the improvements of Watt were first made known), is estimated as *equivalent to the manual labour of upwards of four hundred millions of men, or more than double the number of males supposed to inhabit the globe.** How startling are such statistics;—how eloquently is the panegyric of the inventor thus expressed by the stupendous works of his genius!

As a kinsman of the illustrious engineer,—as long the intimate friend and now one of the executors of his son,—and as the son-in-law of the late Mr. Boulton, the author has enjoyed the peculiar privilege of unrestrained access to the stores of original documents, as well as of anecdotes, by which this volume has been enriched. This circumstance may be a sufficient guarantee of the genuineness and interesting nature of the materials from which he has had to select; and the care bestowed in moulding them to their present form will be well repaid, if it secures a complete and accurate history of the life of one whom the common consent of mankind has now placed "at the head of all inventors, in all ages " and nations."

---

* 'Quarterly Review,' vol. civ. p. 411. 1858.

The checkered career of so great a man,—now dark with shadows, now bright with lights,—may well teach the stern truth,—

"That life is not as idle ore,

"But iron dug from central gloom,
"And heated hot with burning fears,
"And dipp'd in baths of hissing tears,
"And batter'd with the shocks of doom

"To shape and use:"*—

yet it is full of hope and encouragement to those who read its lesson aright. For it sets forth the dignity of that intellectual pre-eminence, which crowns perseverance in honourable toil;—the lustre of that nobility of soul, which finds its highest scope even amid humble pursuits;—the majesty of that wisdom, which intently, tranquilly, and reverently searches out the mysterious works and ways of Creation.

"Fame is no plant that grows on mortal soil,
"Nor in the glistering foil
"Set off to the world, nor in broad rumour lies;
"But lives and spreads aloft by those pure eyes
"And perfect witness of all-judging Jove;
"As HE pronounces lastly on each deed,
"Of so much fame in Heaven expect thy meed."†

---

* Tennyson, 'In Memoriam,' § cxvi.

† Milton, 'Lycidas,' l. 78-84.

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LIFE OF WATT.

CHAPTER I.

INTRODUCTION — INVENTORS AND THEIR HISTORY — LINEAGE OF JAMES WATT — HIS GREAT-GRANDFATHER — HIS GRANDFATHER THOMAS WATT — BURGH OF CRAWFORDSDYKE — BURGH OF GREENOCK — LIFE AND PURSUITS OF THOMAS WATT — HIS MARRIAGE — AND DEATH.

THE fame of James Watt, great as it unquestionably became in the course of his long and honoured life, has increased since his death in a degree that may, perhaps, be termed unprecedented, being co-ordinate with nothing less than the unlimited development of his own manifold inventions. In the case of illustrious heroes and statesmen, poets, orators, or artists, who have attained the height of their glory in their own time, it often happens that when the excitement of contemporary interest, the influence of power, or the partiality of friendship is removed, the judgment which posterity pronounces on their achievements is not unalloyed by other considerations. Such, however, has not been the case with the inventor of the modern steam-engine:—

> "Crescit occulto velut arbor ævo
> "Fama Marcelli,"—

and the renown of so great a promoter of the arts of civilization and the blessings of peace, elastic and expansive as that mighty agent which he first taught men truly to regulate and use, appears, with a steady progression, to have become as universally diffused as the all-pervading power of STEAM.

The respect which in all ages and countries has ever been paid to inventors seems, indeed, to rest on something more profound than mere gratitude for the benefits which they have been the means of conferring on mankind; and to imply, if it does not express, a consciousness that by the grand and original conceptions of their minds they approach somewhat more nearly than their fellows to the qualities and pre-eminence of a higher order of being. "The dignity," says Lord Bacon, "of this end of endowment of man's life with "new commodity appeareth by the estimation that antiquity "made of such as guided thereunto; for whereas founders of "states, lawgivers, extirpators of tyrants, fathers of the people, "were honoured but with the titles of demigods, inventors "were ever consecrated among the gods themselves." * Of all the inventions which the ingenuity of man has devised, that of the modern steam-engine is, whether we regard its own mechanism and mode of performing its operations, or the operations themselves, perhaps the most wonderful, and certainly the most useful. "We must confess," says Belidor, "that this is the most marvellous of all machines, and that "there are none of which the mechanism has so much analogy "to that of animals. Heat is the principle of its motion; in "its different pipes there takes place a circulation like that of "the blood in the veins, having valves which open and shut "themselves at right times; it feeds itself, performs its "evacuations at regular intervals, and draws from its own "work all that is needful for its subsistence."† So, Wordsworth and Coleridge, when on a tour in Scotland, "passed," says Dr. Wordsworth, "a steam-engine, and Wordsworth made "some observation to the effect that it was scarcely possible "to divest oneself of the impression, on seeing it, that it had "life and volition. 'Yes,' replied Coleridge, 'it is a giant "with one idea.'"‡ Thus, the multiplication of diversified forms and effects which the living energies of machinery mysteriously call forth from shapeless, inert, and apparently inadequate materials,—the diminution of labour,—the abridgment of time,—the annihilation of distance, which

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* Fragments of Valerius Terminus, on the Interpretation of Nature; Works of Bacon, by Basil Montagu, 1825, vol. i. p. 266.

† Belidor, Archit. Hydraul., vol. ii. pp. 324, 325, ed. 1739.

‡ Life of Wordsworth, vol. ii. pp. 447, 448, ed. 1851.

the skilful employment of steam enables us to attain, seem little less than emanations from the awful attribute of creative power; and strikingly exemplify that Divine omnipotence and wisdom which inspired the genius to conceive and bestowed the ability to produce them. It is recorded of Mrs. Siddons that when in the Louvre, in 1814, she beheld the statue of the Apollo Belvidere, she exclaimed, "What a great "idea it gives us of God, to think that He has made a human "being capable of fashioning so divine a form!" So when we behold the steam-engine, in all its varied forms and applications, producing its manifold works with what seems to be almost human intelligence, and even superhuman power, it is perhaps not too much to say that we may feel our conceptions of the ETERNAL WISDOM enlarged by the reflection that HE formed that mind which was capable of devising mechanism at once so simple and so sublime.

In proportion to the estimate which men have formed of the importance of the inventor's work is generally the desire they feel to learn the history of its origin and progress; and of the development of the mind of its contriver. It will be seen from the following pages, that the life of the creator of the modern steam-engine was one, as has been justly remarked, of patriarchal simplicity, "devoted to labour, to "study, to meditation;" and that in a humble condition, and a career of virtuous industry and patient thought, "projects "were elaborated, which were destined to raise the British "nation to an unheard-of height of power."

The first of the paternal ancestors of James Watt, of whom any notices have been preserved, is his great-grandfather; the minute details of whose personal history, however, have shared nearly the same oblivion in which even his Christian name is sunk. It is only known, from the traditions of his family, that he lived in Aberdeenshire in the earlier half of the seventeenth century, and followed the business of a farmer, whether of his own land or not we can only conjecture; that his peaceful pursuits did not exempt him, in "the troubles" of that period, from a rude summons to arms, and an early death in battle; that he perished in one of the wars of Montrose, fighting, in all likelihood, for the cause of the Covenant; that his property was confiscated; and that his orphan son, Thomas, educated by the care of some distant relations, thus received that blessing promised to the fatherless, to compensate their loss.

Where those relations lived who thus benevolently rescued from destitution the poor orphan, does not appear. He was born, according to one account, in 1639, according to another in 1642, and was at all events soon removed from Aberdeenshire—a county which at that time suffered more than perhaps any other part of Scotland from the scourge of civil war, and which, according to the lamentable account given by Spalding in his 'Memorialls of the Trubles in Scotland and 'in England, A.D. 1624–A.D. 1645,' was left "almost man-"less, moneyless, horseless, and armless, so pitifully was the "same borne down and subdued."

Thomas Watt settled, early in life, in the little burgh of barony of Crawfordsdyke, or Cartsdyke, situated in the barony of Cartsburn, in the close vicinity of the town of Greenock in Renfrewshire. He was a "teacher of naviga-"tion;" or, as he is styled on his tomb-stone, "Professor of "the Mathematicks;" a vocation for the exercise of which it appears that neither Cartsdyke nor Greenock could, previous to that time, have afforded any very wide scope. Greenock was erected into a burgh of barony by a charter of Charles I., granted 5th June, 1635, and ratified by an Act of the Parliament of Scotland in 1641; and, according to the best information extant on the subject, the erection of Crawfordsdyke into a similar burgh took place in 1669. But neither place became very populous or busy for many years afterwards; and even so late as April 1700, in an enquiry for settling the amount of taxation to be made in respect of their trade, it was given in evidence that the whole shipping of the two burghs together consisted but of one ship belonging wholly to Greenock; three ships having part-owners in Glasgow; and two barks and a traveller-boat, said to belong to Greenock. In this estimate there can be no doubt that the open or half-decked boats employed in the herring or other fisheries were not included; for even then those resources of the Western Frith were opening up an extensive and valuable business, and might indeed be looked upon as the nursery of those excellent seamen who were soon to be employed in making longer voyages, as well as of that enterprise and capital which the merchants of Glasgow, Port-Glasgow, and Greenock, were to embark in the great system of commerce which they have since created. But still, the enumeration above-mentioned presents a marvellous contrast with the present state of the Frith of Clyde, when, after the interval of only a century and a half, we see its waters covered with the sails of thousands of merchant vessels, and its air darkened with the smoke of almost innumerable steam-boats.

That learned antiquary, William Hamilton of Wishaw, in his volume of 'Descriptions of the Sheriffdoms of Lanark 'and Renfrew, compiled about M.DCC.X.,' which was printed at Glasgow in 1831, for the Maitland Club, gives the following description of the two sister burghs as they appeared in his time:—

"About two miles down from Newark, upon the river of "Clyde, is the house, town, and parish of Greenock. This "parish is of no old erection. But the Lairds of Greenock "having given incouragement to build, leave and inhabite "there, that the town so increased as the Laird was incou-"raged to build ane church there; and got severall lands "disjoyned from neighbouring parishes, which makes up this "parish of Greenock. And the town of Greenock is now "erected in ane burgh of barronie; hath ane good harbour "for vessels, and is become a place of considerable trade, "and is like more and more to increase, as specially if the "herring fishing continue in the river of Clyde: for as that "fishing necessarly follows the sweaming of the herring, so "when they sweam in Clyde or in the lochs adjoyning to it, "as frequently they doe towards the end of the year, it occa-"sions a confluence of many thousands of people to these "pairts, which yearly continowes a considerable space.

"The last Laird of Greenock, Sir John Schaw, did won-"derfuly augment his fortune, so as he left one of the best

" gentlemen's estate to his sone in all that country. . . .
" There is very expensive works lately built about the house, " gardens and parks of Greenock, which exceadingly beautify " the place; and he hath singularly repaired and beautifyed " the church.

" Near to the town of Greenock is the town of Carsedyke, " lyand upon the river of Clyde, a litle to the east of " Greenock. It is erected in a burgh of barrony, and hath a " very convenient harbour for vessels. It belongs to the " Laird of Carseburn, Crawford, who is brother sone to the " Laird of Jordanhill, who hath a convenient house and " dwelling ther, att Carseburn.—The town is mostly subfewed " to merchands, seamen, or loadingmen, who have built very " good houses in it; and is a very thriving litle place."

The population of Crawfordsdyke and of Greenock must, at the time of Thomas Watt's settlement there, have been small; for we learn that nearly a century later it amounted to no more than four thousand one hundred souls in the whole parish. We may reasonably wonder at any teacher of mathematics whose practice was limited to so narrow a field, being able to derive even a sufficient subsistence from his erudite labours. Yet not only did he maintain himself and his family, in respectability and comfort, on the limited earnings of such humble but honourable toil, but he also accumulated funds sufficient to enable him to purchase the house in Crawfordsdyke in which he lived, with a garden attached, and afterwards a house in Greenock; neither of them, however, being the house which afterwards became famous as the birth-place of his eminent grandson. "The " house" (in which Thomas Watt lived), says Mr. Williamson, " was situated on the east side of the bottom of the " street known by the name of *The Stanners*," (so called from the standard or weighing-machine which stood next door to Mr. Watt's house), " and had a slanting front to " what was then, and still is, the chief street or thoroughfare " leading from Greenock towards Port-Glasgow. To the " house and garden here mentioned he acquired right by " charter from the superior on 6th March, 1691. . . . The

“ house was, about 35 years ago, pulled down and rebuilt. “ Besides this property in Crawfordsdyke, Thomas Watt, as “ before stated, was proprietor of another house in the town “ of Greenock, which was situated at the ‘open shore,’ and “ occupied part of the site of the large fabric fronting the “ short lane leading to what is now Shaw Street, from the “ new graving dock.”[*]

He seems to have been highly esteemed among his worthy brother-citizens of the burgh; over which he was made chief magistrate, or “Baillie of the Barony;” he also became an Elder of the Parish and Presbytery, as well as Treasurer and Clerk to the Kirk-Session, ecclesiastical dignities which must be supposed to bear witness to the integrity of his life; and proofs remain of the nature of his dealings with men and things in each of those capacities, which demonstrate the rigidity of the rule he maintained over the minds and morals of the little community. Repairing the church,—widening the bridge,—trying by mathematical standards the weights and measures used in the burgh,—are associated, in the records of the court in which he presided, with his infliction of penalties for assault and battery of the lieges, his threatening with “ the pain of fourtie shillings Scots, *toties quoties*,” “ several of the young ones who does upon that night called “ Hallowin night abuse several yards in drawing of kail,”[†]—

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[*] ‘Memorials of the Lineage, ‘ Early Life, Education, and De‘velopment of the Genius of James ‘ Watt, by George Williamson, late ‘ Perpetual President of the Watt ‘ Club of Greenock. Printed for the ‘ Watt Club, 1856,’ p. 58—a work which, not pretending to offer a complete biography of the great man whom it commemorates, was modestly set forth as simply a contribution of accredited facts such as form the basis and material of authentic history. As such it must be viewed as of considerable value, and will be often referred to in these pages; while the liberal and enthusiastic zeal which prompted its commencement and ensured its completion is to be commended as worthy of all imitation.

[†] “The first ceremony of Hal“ loween is pulling each a stock or “ plant of kail. They must go out, “ hand in hand, with eyes shut, and “ pull the first they meet with: its “ being big or little, straight or “ crooked, is prophetic of the size and “ shape of the grand object of all their “ spells,—the husband or wife. If any “ yird, or earth, stick to the root, that “ is tocher, or fortune; and the taste “ of the custock, that is, the heart of “ the stem, is indicative of the natural “ temper and disposition. Lastly, the “ stems, or, to give them their or“ dinary appellation, the runts, are “ placed somewhere above the head “ of the door; and the Christian “ names of the people whom chance “ brings into the house are, according “ to the priority of placing the runts, “ the names in question.”—ROBERT BURNS.

his statuting and ordaining that "in all time comeing, if any "persons keip hens, and they doe prejudice to any neighbour, "that the owner sall mak up the damnage attour lyable in "fourtie shilling *toties quoties*. This act extends to all sorts "of taim foules;"—and many other instances of discipline, equally minute, equally solemn, and doubtless, equally salutary. "Sitting in and haunting taverns, on Friday and "Saturday nights," was, under the reign of his exemplary censorship, to be "abstained from after nine of the clock, "at which time the bell of the kirk is allowed to be "rung, to give advertisement to all to repair to their own "house, except in case of necessity;"—offending skippers were made "to acknowledge their guilt" in "loosing their "ships and taking them to seaward on the Sabbath Day," and were then held to be cheaply let off by being "censured "with a sessional rebuke, and admonished to carry more "tenderly on the Lord's Day for the future."

But the greatest eruption of the volcano of vice which then threatened to overwhelm Carsdyke with its torrent of moral lava, probably occurred when "the Minister informed the "Session that mountebanks having come to the place, had "erected a stage for a stage-play to be acted thereon, "and proposed" — (*i. e.* the Minister,—not the mountebanks!)—"they should fall on some effectual method for "suppressing the same." And "the Session, considering the "thing to be unlawful, and inductive of much sin and loose-"ness, appointed some of their number, to wit, James Craw-"ford, John Clark, and Thomas Watt, to go to the "Doctor"—(not the Minister, but the quack-mountebank), "in name of the Session, and discharge him to use rope-"dancing, and men simulating themselves fools, or women "exposing themselves to public [gaze] by dancing on the "stage, or any indecent behaviour, allowing him only to ex-"pose his drugs or medicines to public sale." It is not always necessary for men to "simulate themselves" fools in order to show themselves to be so; but, without intending any reflection on the venerable kirk-session, it may be questioned how far their exception of the "drugs or medicines" from the general anathema could have been beneficial to the bodies of the worthy burghers, any more than the antics of the merry-andrews and their fair but too frolicsome companions were likely to promote the welfare of their souls. The desire to partake of the one, however, would doubtless be less general than the longing to witness the other; and could not readily be suspected of any tendency towards dangerous over-indulgence.

The name of Thomas Watt's wife was Margaret Sherrer; by her he had six children, of whom Margaret, Catherine, and Thomas, all died in infancy, and Doritie,—so the name is spelt,—at the age of eighteen. Thomas Watt died on the 27th of February, 1734, "aged about 95 years," and his widow on the 21st of March, 1735, "aged 84 years," as stated in the Register of burials of the Old or West parish of Greenock; or 92 and 79 years respectively, as engraved on the tomb-stone of Thomas Watt and his family, in the church-yard of the same parish. Of the two accounts, the former is the more trustworthy, at least one error having certainly been committed by the workman employed in cleaning and deepening the inscription on the tomb-stone, in 1808; for he unwittingly altered the date of Mrs. (Thomas) Watt's death from 1735 to 1755, which, besides making her thirty-four years older than her husband, is known to be erroneous from the short interval that occurs in the Register between the record of his death, in 1734, and that of her own.

CHAPTER II.

JOHN AND JAMES WATT OF GREENOCK — SCENERY OF THE FRITH OF CLYDE — RAPID PROGRESS IN THE NAVIGATION OF THAT RIVER — LIFE AND PURSUITS OF JAMES WATT OF GREENOCK, FATHER OF THE GREAT ENGINEER — AGNES MUIRHEID, HIS WIFE — MUIRHEADS OF LACHOP — FLODDEN FIELD — CHARACTER AND DEATH OF AGNES MUIRHEID OR WATT — HER BROTHER, JOHN MUIRHEID.

Two sons of Thomas Watt, John and James, grew up to man's estate, surviving their parents; and both of them appear to have been diligently trained by their father in his own pursuits; in which John, the elder of the two, was for some time able to be of service in assisting his kind instructor. In 1712, John Watt, being then twenty-five years of age, was appointed clerk to the barony of Cartsburn, and burgh and barony of Crawfordsdyke, of which his father was for many years the baillie. But he soon quitted Greenock for Glasgow, to seek a wider field for the exercise of his profession; and there, as a surveyor, he obtained considerable practice; dying unmarried, at the age of fifty, in 1737. He left behind him a Survey of the course and Frith of the river Clyde, from above Rutherglen and Dalbeth on the East, to Loch Ryan, Portincross, and the coast of Ireland on the South, and the islands of Islay, Colonsay, and part of Mull on the West. This Survey was made in 1734; it was engraved in 1759, and published in 1759-60, by the united cares of his brother James, and of his two nephews, John and James; of whom the one perished at sea two years afterwards, on a voyage to America in one of his father's ships, at the age of twenty-four, and the other was the great engineer.

"The Survey," writes the latter in 1794, "as far as the "Point of Toward, was done by my uncle before I was "born; the remainder was added by my father and my "brother, but is not over accurate." Several alterations were made on the map, by the engineer's own hand, before it was engraved; particularly on that portion of it, comprehending the islands of Mull, Islay, &c., which occupies a separate division of the map, and is entitled "Entry to the River and Firth of Clyde and adjacent "islands, according to the best authorities." As copies of the original engraving are now very rarely met with, (we know of only three), we may add, for the information of those curious in such matters, that the name of the engraver was Thomas Phinn, Edinburgh; that the size of the copperplate was 29×21 inches; and that the impression struck off in 1759 consisted of 450 copies. The expense of engraving and printing was 20*l.*, and the impressions were, about a century ago, sold at 2*s.* 6*d.* each. For the possession of an excellent copy, rendered additionally interesting by some MS. additions of dates and names in the hand-writing of the great engineer, we are indebted to the kindness of the late William Davie, Esq., LL.D., the much-respected principal Town-clerk of the city of Glasgow. And the Watt Club of Greenock have done honour to themselves, and good service to the public, by printing an excellent lithographic fac-simile of the Survey, reduced to somewhat less than two-thirds of the size of the original; on which, also in most truthful fac-simile, are given the MS. notes already spoken of.

It is extremely interesting to trace on the map-chart so prepared, the course of the Clyde throughout that important part in which alone it can be called a navigable river; a term which then could be applied to it only with the very greatest restrictions. For we there see that its channel at that time was almost entirely filled with sand-banks and wide-spread beds of accumulated alluvial gravel and mud; that at Dumbuck, half-way between Greenock and Glasgow, where now great Indiamen and magnificent steamers of all but Leviathan size can pass in safety with their freights, there actually was at low water *a ford*, the soundings on which were at the greatest height of high-water not more than nine feet; that at Glasgow there was but one bridge, where now there are five; and that the streets of that city, now between five and six hundred, were then not more than a tenth of that number, as another century earlier they had been called but *four*. But perhaps the spots which on the whole chart most deserve notice, are the microscopic harbour of Greenock, and the still more modest "jetty" of "Carsdyk," with the few and humble habitations attached to those two new-born burghs respectively; out of which there was to come one whose mighty destiny it was to be to raise his country to an eminence of power and wealth unexampled among nations, and to work a change on the whole face of the habitable globe, of which, as yet, we perhaps see only the vast beginnings, and of which no human foresight can pretend to predict the inconceivable results.

But at the date to which our narrative had brought us these things were not yet; and we must return to the little burghs, reposing in all their early simplicity and pious peacefulness, "fast by" the fair frith of the river Clyde, and sheltering under their friendly roofs one generation after another of the creditable and mathematical family of Watt. James, the younger son of Thomas Watt, was born on the 28th of January, 1699, and is said, after having served an apprenticeship to a builder and shipwright in Crawfordsdyke, to have settled in Greenock about the time of his marriage in 1728 or 1729, when, consequently, he must have been on the verge of thirty years of age. If not so deeply versed in the theories of abstract science as either his father or his brother,—or, we need scarcely add, as his illustrious son,—he seems to have been not less energetic in the practice of those useful occupations to which he devoted his life. They were, in his case, a somewhat multifarious compound of commerce, and of the more ordinary handicraft arts required for the purposes of commercial and seafaring men; he was a shipwright; a ship-chandler, supplying vessels with nautical apparatus, stores and instruments; a builder; and a merchant. For upwards of twenty years he was a member of the Town Council of Greenock, and, during great part of that time, its Treasurer; a magistrate; and always a zealous and enlightened promoter of the improvements of the town of which he was an inhabitant. Above all, it is recorded by one who knew him well, that he was an intelligent, upright, and benevolent man; and, although he probably never expected that the good he did, should be thus made to "live after him," but rather that it should be "interred with his bones," yet in his case, as in many others of equally unpretending virtue, it has thus happened that

> " ——— the actions of the just
> " Smell sweet, and blossom in the dust."

The lady whom James Watt of Greenock married was Agnes Muirheid, or Muirhead, (for the name was indifferently spelt in either way), "a fine-looking woman, with pleasing, " graceful manners, a cultivated mind, an excellent under-" standing, and an equal, cheerful temper." She was descended from a branch of a family of some note in the early history of Scotland, "settled in the shire of Clidesdale time " immemorial, and certainly before the reign of David the " First of Scotland, anno 1122, and were a distinct people by " themselves, who never acknowledged any superior, but " were Liberi tenentes Regis et Coronæ, and have always " been great soldiers and warriors." The ancient family of the Muirheads of Lachop, who were chiefs of their clan, gave to the see of Glasgow, in 1454, (before its erection into an archbishopric), its pious and learned Bishop Dr. Andrew Muirhead, who in 1468 was sent as ambassador to Copenhagen, to settle the marriage of Margaret "the Maid of " Norway" to King James III.; and, in 1494, the same family supplied the realm of Scotland with a Lord Clerk Register, Judge, and Secretary of State, in the person of Dr. Richard Muirhead, Dean of Glasgow. But the most glorious, though disastrous fate of the Muirheads, clan and chieftain alike, befell them on the fatal day of Flodden field,—"in campo " belli de Northumberland, sub vexillo Domini Regis,"— where they occupied the post of honour and of danger as the body-guard of the King. There, when, as the old song has it, " The English, *for ance*, by guile wan the day," they sealed their loyal devotion to their monarch with their blood; and Sir Walter Scott, in his 'Minstrelsy of the Scottish Border,' has preserved the record of their fatal feat of arms in the old ballad of "THE LAIRD OF MUIRHEAD."

" Before the King in order stude
" The stout Laird of Muirhead,
" Wi' that same twa-hand muckle sword
" That Bartram fell'd stark dead.*

" He sware he wadna lose his right
" To fight in ilka field,
" Nor budge him frae his liege's sight
" Till his last gasp should yield.

" Twa hunderd mair, of his ain name,
" Frae Torwood and the Clyde,
" Sware they wad never gang to hame,
" But a' die by his side.

" And wondrous weill they kept their troth :
" This sturdy royal band
" Rush'd down the brae wi' sic a pith
" That nane could them withstand.

" Mony a bludey blaw they delt,
" The like was never seen ;
" And hadna that braw leader fall'n,
" They ne'er had slain the King."

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* 'Minstrelsy of the Scottish Border,' vol. i. p. 283, ed. 1803. "The tradition goes, and as I had it from a learned and curious antiquary, who was also a gentleman of great reputation and integrity—I mean my most worthy friend William Hamilton of Wishaw—that the Laird of Muirhead of that ilk—de Muirhead, as I have often found them designed in the time of King Robert II.—got the lands of Lachop and others for assaulting and killing a great robber that infested all that part of the country by violent ravages and depredations, which he carried to a very insufferable degree; so that at length the government were obliged to take notice of him, and by a public act notified 'that whosoever should apprehend, kill him, or bring him to justice, should be rewarded with such and such lands.' His name, the tradition tells us, was Bartram de Shotts: he was a terror to every body that resided near him, or who had occasion to pass east or west through those parts where he lurked and had his haunts. The Laird of Muirhead at the time was a bold, daring, intrepid man; he did not surprise him in his lurking-places, but with a few in his company, to whose courage and valour he could well trust, came up, and in the daytime attacked him in that valley on the east side of the Kirk of Shotts, when, after a pretty smart encounter, the Goliath Bartram was slain on the place. The Laird of Muirhead cut the head off this robber, which he carried straight to the King, who immediately, in the terms of the proclamation, ordered him a charter and infeftment of those lands that were then, or soon after, called Lachop, and gave him, as an additional honour to his arms, the three acorns in the seed, on the bend dexter; for crest, two hands supporting a sword in pale, proper; and the motto, AUXILIO DEI, which is borne by the family to this day."—Account of the Family of the Muirheads in Nisbet's 'Heraldry,' vol. ii. Appendix, p. 258.

Agnes Muirheid lived in happy wedlock with James Watt of Greenock for a quarter of a century, and died in 1755, aged 52. Her portrait, which is still in existence, well executed in oil colours, seems to justify the encomiums passed by those who knew her, on the great comeliness of her countenance; and on the quiet good sense and serene composure of her mind. In Mr. Williamson's volume her likeness is thus drawn, and all that we have ever heard concerning her confirms the truth of the portraiture:—" A gentlewoman of good " understanding and superior endowments, whose excellent " management in household affairs would seem to have con- " tributed much to the order of her establishment, as well as " the every-day happiness of a cheerful home. She is de- " scribed as having been a person above common in many " respects, of a fine womanly presence, ladylike in appearance, " affecting—according to our traditions—in domestic arrange- " ments, what it would seem was considered, for the time, " rather a superior style of living. . . . Our venerable " informant described James Watt's mother—in her eloquent " and expressive Doric—as '*a braw, braw woman,—none now to* " '*be seen like her.*'" If it be true that from the mother chiefly are derived the natural temper, disposition, and abilities of the child, we cannot err in giving all the information we possess as to those which characterised the mother of James Watt. It is said that her death was preceded by a singular dream, in which " she heard a voice requiring her to prepare for " appearing within three days before the judgment-seat of " CHRIST;" and that within three days thereafter she suddenly died.*

John Muirheid, the brother of Mrs. Watt, and James Watt her husband, were united in many mercantile adventures, though without entering into any formal articles of partnership. There was indeed no occasion for the constraint of such fetters, where the parties were both secure of each other's disinterested honour, and sufficiently connected by the ties of affinity and mutual affection; and although Mr. Watt, in the latter part of his life, experienced heavy commercial losses, which swept away a great portion of the respectable fortune which his assiduous industry had realised, we believe those to have arisen from enterprises with which no member of his brother-in-law's family was in anywise associated. Mr. John Muirheid died in 1769, leaving to his son Robert the beautiful estate of Croy Leckie, in the parish of Killearn, and county of Stirling.

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* Memorials of Watt, p. 154.

CHAPTER III.

CHILDREN OF JAMES WATT OF GREENOCK, AND AGNES MUIRHEID — BIRTH OF JAMES WATT — JOHN WATT, HIS YOUNGER BROTHER — JAMES WATT'S CHILDHOOD — HIS HOME, EDUCATION, AND FEEBLE HEALTH — MRS. CAMPBELL'S MEMORANDA OF HIS EARLY YEARS — HIS POWERS OF IMAGINATION — HIS FIRST OBSERVATION OF THE CONDENSATION OF STEAM — VARIETY OF HIS YOUTHFUL STUDIES AND PURSUITS.

To Mr. Watt of Greenock and Agnes his wife, there were born five children; of whom the three eldest,—two sons and a daughter,—died in infancy or early childhood. The fourth was James, the subject of this biography, who was born on the 19th day of January, 1736; and the fifth was John, who was born in 1739, and died at sea, as has already been mentioned, in 1762. Premature as was his fate, he was yet able, as we have seen, to assist his father and elder brother in completing the survey of the Clyde which had been left unfinished by his uncle of the same name; and as that survey was engraved and published in 1759-60, his aid in that family undertaking must have been given before he was twenty-one. He had been destined to follow his father's business, and the fatal voyage to America, on which he was sent while still so young, was probably considered as likely to prove highly advantageous, by increasing his experience of nautical affairs, and enlarging the horizon of his observation, before he should again settle down, either in the family home, or in some other sphere. How far he might have been able to keep pace with his gifted brother in the career on which he was so soon to enter, is a problem that must remain for ever unsolved; but it is curious to observe how decidedly a turn for scientific pursuits seems, in some measure at least, to have been common to every male of that family, so as to have become almost the birthright of both of the grandsons of Thomas Watt, "the old mathematician." And it may be added, that the same inclination continued to "run in their "veins," till the line of direct male descent itself became extinct, by the death, without issue, of both of the sons of the illustrious improver of the steam-engine.

The childhood of James Watt presents us with the spectacle, only too frequent in the histories of men of genius, of great delicacy of constitution, and consequent inability to bear an equal part in either the toils or the sports common to other boys of his own age. But the same excellent authority on which we know that in his early years he was physically sickly and feeble, has also told us that:—"When he was "six years of age, a gentleman calling on Mr. Watt observed "the child bending over a marble hearth, with a piece of "coloured chalk in his hand. 'Mr. Watt,' said he, 'you "'ought to send that boy to a public school, and not "'allow him to trifle away his time at home.' 'Look "'how my child is occupied, before you condemn him,' "replied the father. The gentleman then observed, that the "child had drawn mathematical lines and circles on the "marble hearth, and was then marking in letters and figures "the result of some calculation he was carrying on; he put "various questions to the boy, and was astonished and gratified with the mixture of intelligence, quickness, and simplicity, displayed in his answers. 'Forgive me, Mr. "'Watt;—this boy's education has not been neglected:—he "'is no common child.'"

"His parents were indulgent, yet judicious in their kindness; and their child was docile, grateful, and affectionate. "From an early age, he was remarkable for manly spirit, a "retentive memory, and strict adherence to truth; he might "be wilful or wayward, but never was insincere. His faults "were ever acknowledged with candour, and, when any "quarrels occurred with his young friends, his father said, "'Let James speak; from him I always hear truth.'"

"He received from his mother his first lessons in reading; "his father taught him writing and arithmetic. Owing to "variable health, his attendance on public classes at Greenock was irregular; his parents were proud of his talents,

" and encouraged him to prosecute his studies at home. His " father gave him a set of small carpenter's tools, and one of " James's favourite amusements was to take his little toys to " pieces, reconstruct them, and invent new playthings." Every one must admire the enlightened affection which could, amid all the happy little works and ways of home, allow to the intelligent boy a latitude such as, in those days of rigid paternal discipline, was perhaps unusual, but not misplaced; which could with watchful kindness supply every reasonable wish and want, suggest every cheerful and thoughtful occupation, and yet refrain from urging, in hours of illness or languor, the opening mind to more sustained exertions, thus avoiding all risk of overstraining its energies, and of weakening its powers.

Of the boyish years of the future mighty engineer, various incidents have been recorded,—some of them slight and trivial enough, such as are those of the little respect in which his school companions are said to have held his abstracted and contemplative nature, his silent sufferings as an invalid, and his consequent disinclination, — and, indeed, inability,—to mix in boisterous play and unmeaning idleness; as well as of the slowness with which most of them awoke to the conviction that "Jamie Watt" was "no vulgar boy," and was likely to prove no illiterate one. The report, however, of "a certain mental dulness" said to have been "exhibited by him during the earlier period " of his school days," rests only on the opinion, conceived at that early age by one or two of those very comrades,— "burly youngsters," as they have been appropriately termed;—and naturally leads us to remark that it appears to be rather inconsistent with that other record which we have just been transcribing. In a conflict of such authorities, we could not for a moment hesitate as to which ought to command our belief; nor could we adopt as matter of fact the opinion alleged to have been held on this subject by some venerable survivors of the number of Watt's school companions, without confessing how great must have been the mental brilliancy, at the same age, of those early cynics who could feel such pity for the comparative intellectual weakness of James Watt!

But another explanation presents itself, which enables us to reconcile any apparent discrepancy between the two statements. We trust that we do no injustice, nor show any undue disrespect to the memory of the worthy personages more immediately referred to, if we venture to suggest that between their views, their habits of thought, and subjects of reflection, and those of James Watt even in his boyhood, there may have been, and there probably was, so wide a difference, as to make him no very congenial companion for them, nor them very competent judges of him. The day-star might all the while be dawning, and even shining more and more unto the perfect and glorious day; and yet its light might be slowly discerned by eyes habitually bent towards the earth.

Fortunately it happens that other anecdotes, of quite a different sort, have also been preserved, relating to the same early period, which are of great value in every way, and far too curious to be here omitted. Their tendency is uniform, and in one direction; while the authenticity of the MS. notice from which they are taken is unimpeachable, and its exactness has been effectually guaranteed. The document in question is entitled 'Memoranda of the early years of 'Mr. Watt, by his cousin, Mrs. Marion Campbell (born 'Muirheid, daughter of his mother's brother), who was his 'companion in early youth, and friend through life; dictated 'to and written down by her daughter Miss Jane Campbell 'in 1798.' In thanking Miss Campbell in 1834 for a transcript of that paper, the late Mr. Watt of Aston Hall, (son of the great engineer), assured her that he attributed the greatest value to a record which he justly described as containing information at once so full and so specific; and remarked that it was so accordant with all he had himself known of his revered father's character in later years, that he entertained not a doubt of its perfect accuracy.

"That his powers of imagination and composition," says Mrs. Campbell, "were early displayed, appears from the "following incident. He was not fourteen when his mother "brought him to Glasgow to visit a friend; his brother John "accompanied them: on Mrs. Watt's return to Glasgow some "weeks after, her friend said, 'You must take your son James "'home; I cannot stand the state of excitement he keeps me "'in; I am worn out with want of sleep; every evening before "'ten o'clock, our usual hour of retiring to rest, he contrives "'to engage me in conversation, then begins some striking "'tale, and, whether humorous or pathetic, the interest is so "'overpowering, that all the family listen to him with "'breathless attention; hour after hour strikes unheeded; in "'vain his brother John scolds and pulls him by the arm, "'Come to bed, James; you are inventing story after story "'to keep us with you till after midnight, because you love "'company, and your severe fits of toothache prevent your "'sleeping at an earlier hour.'

"Sitting one evening with his aunt Mrs. Muirheid at the "tea-table, she said: 'James Watt, I never saw such an idle "'boy: take a book or employ yourself usefully; for the last "'hour you have not spoken one word, but taken off the lid "'of that kettle and put it on again, holding now a cup "'and now a silver spoon over the steam, watching how it "'rises from the spout, and catching and connecting the "'drops of hot water it falls into. Are you not ashamed of "'spending your time in this way?'"

"In the year 1750," said M. Arago, in addressing the assembled members of the Institute of France, "each one of "us, in the same situation as Mrs. Muirheid, would perhaps "have used the same language. But the world has made a "stride, and our knowledge has grown greater; and so, when "I shall immediately explain to you that the principal dis"covery of our fellow-member was a particular mode of con"verting steam into water," [the condensation of steam in a separate vessel from the boiler], "Mrs. Muirheid's reproof will "present itself to our minds under a totally different aspect: "the little James before the tea-kettle becomes the mighty "engineer preluding to the discoveries which were to immor"talise him; and it will, by every one, undoubtedly be

" deemed worthy of remark, that the words CONDENSATION " OF STEAM should naturally have come to find a place in the " history of Watt's early childhood."

Mrs. Campbell's narrative continues:—" It appears that " when thus blamed for idleness, his active mind was em- " ployed in investigating the properties of steam: he was " then fifteen, and once in conversation he informed me that " before he was that age he had read twice, with great atten- " tion, S'Gravesande's Elements of Natural Philosophy;* " adding that it was the first book upon that subject put into " his hands, and that he still thought it one of the best. " When health permitted, his young ardent mind was con- " stantly occupied, not with one but with many pursuits. " Every new acquisition in science, languages, or general " literature, seemed made without an effort. While under " his father's roof, he went on with various chemical experi- " ments, repeating them again and again until satisfied of " their accuracy from his own observations. He had made " for himself a small electrical machine, and sometimes " startled his young friends by giving them sudden shocks " from it."

We pause here to remark that in point of novelty, and, indeed, also of the mental capacity required to apprehend its true nature and construction, an electrical machine was in those days a very different thing from one made or used at the present time. For young Watt's performance must have been about the years 1750-53; and, as many of our readers are aware, the Leyden phial was not invented till the years 1745-46.†

" His early years were passed in Greenock; from the age " of fourteen he was often in Glasgow with his uncle Mr. " Muirheid, and read and studied much on chemistry and

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* 'Physices Elementa Mathematica ' experimentis confirmata, sive Intro- ' ductio ad Philosophiam Newtoni- ' anam. Auctore Gulielmo Jacobo's ' Gravesande, A.L.M. Jur. Utr. et ' Phil. Doctore, Regiae Societ. Lond. ' Socio; Astron. et Math. in Acad. ' Lugd. Bat. Professore ordinario. ' Lugduni Batavorum, M.DCC.XX.' 2 vols. 4to. This work was translated into English in the same year, and afterwards went through many editions in that language.

† See Priestley's History of Electricity, p. 80, edit. 1769.

" anatomy. He took a deep interest in this latter subject, " and in all connected with the medical art, and was once " observed carrying off a child's head that had died of some " uncommon complaint." Mr. Watt continued through life much attached to the medical art, and had deeply studied his own constitution. He treated his own complaints, and those of his family and friends, *secundum artem;* and told his son, that had he been able to bear the sight of the sufferings of patients, he would have been a surgeon.

" Under Mr. Muirheid's roof he met with good society, and " formed friendships with several intelligent and well-educated " young men; they had frequent evening meetings to give or " receive information. These gentlemen acknowledged and " appreciated Mr. Watt's superior abilities; his manners were " so kind and unassuming that no jealous feelings were ever " excited; his warm affections and stern integrity commanded " their esteem and regard; yet they sometimes feared while " they loved him, as he had no patience for folly, and could " be sarcastic.

" The agony he suffered from continued and violent head- " aches often affected his nervous system, and left him for " days—even weeks—languid, depressed, and fanciful; at " those times there was a roughness and asperity in his " manner that softened with returning health. He often " passed the summer months in Mr. Muirheid's family, on " the banks of Loch Lomond, near the spot where Buchanan " the historian was born, and the celebrated Napier of Mer- " chistoun passed many years of his life. Mr. Watt was par- " tial to the country, and, when health permitted, entered " with his young companions into its active sports and amuse- " ments. Indefatigable in his habits of research and observa- " tion, every excursion he took extended his knowledge; not " contented with adding to his botanical and mineral treasures, " he entered the cottages of the poor to study their characters, " and listen for hours to their local traditions, popular ballads, " and wild superstitions.

" He enjoyed society in a small select circle; his talents " for conversation were always remarkable; he seldom rose

" early, but accomplished more in a few hours' study than " ordinary minds do in many days. He never was in a hurry, " and always had leisure to give to his friends, to poetry, " romance, and the publications of the day: he read indiscriminately almost every new book he could procure. On " a friend entreating him to be more select in his choice, " he replied, 'I have never yet read a book, or conversed " 'with a companion, without gaining information, instruction, or amusement.' He was alternately very active, " or, apparently, very indolent; and was subject to occasional fits of absence. He had a quick perception of the " beauties of nature, and delighted in exploring the wild " glens of his native land, and tracing to their source " the mountain torrents. Though modest and unpretending, yet, like other great men, he was conscious of his " own high talents and superior attainments, and proudly " looked forward to their raising him to future fame and " honour."

Such, with the exception of a short concluding portion relative to Mr. Watt's married life, which will hereafter be introduced in its proper place, is the whole of Mrs. Campbell's succinct, yet comprehensive narrative. We hope that "the " reverence of kindred" does not unduly influence our judgment, when we venture to express a belief that it will always occupy an honourable place among the annals of the childhood and youth of great men. It is not often, indeed, that so forcible a sketch has been drawn of the early character of one afterwards so highly distinguished, by any artist favoured with such frequent opportunities of close observation of her subject, and at the same time, let us add, with so happy a command of her pencil. We feel well assured that the portrait she has given us of James Watt in his youth, distinct as are its features, and fresh and lively as are its tints, is neither painted in too glowing colours, nor in any way too highly varnished; and that by all who attentively consider it, it will be admitted to bear on its countenance the stamp of a self-evident fidelity.

CHAPTER IV.

SCHOOLS AND SCHOOLMASTERS OF JAMES WATT — ANECDOTES OF HIS BOYISH HABITS AND PASTIMES — PORTRAITS OF NAPIER AND NEWTON — HIS CALL TO BE A MECHANICAL PHILOSOPHER — HIS VISIT TO GLASGOW — ACQUAINTANCE WITH PROFESSORS OF THE UNIVERSITY — JOURNEY TO LONDON — PRACTICE OF MATHEMATICAL-INSTRUMENT-MAKING—RETURN TO SCOTLAND.

DURING the period to which Mrs. Campbell's memoranda chiefly apply, his father's house in Greenock was the head-quarters of young Watt, from which he frequently made such excursions as she has described, to the homes of other kind relations and friends, either during his vacations, or when health rendered change of air and relaxation advisable. The commercial school of a Mr. Macadam he attended, though, as it is said, not very punctually, nor perhaps over diligently; a more than respectable proficiency in Latin, and some knowledge of the elements of Greek, he attained under the tuition of a learned and virtuous person of the name of Robert Arrol, master of the grammar-school of Greenock; mathematics he studied with far greater zest, and with proportionate success, under one John Marr, whose designation is given, in the attestation of some deeds of that date, as "mathematician in "Greenock." Whether our John Marr was any descendant or kinsman of that well-known "excellent mathematician and "geometrician" of the same name, "servant to King James "First and Charles First," mentioned by Lilly in his account of the meeting between John Napier of Merchistoun and Mr. Briggs of Oxford, we know not; although the similarity of name and pursuit seems to give some slight *à priori* reason for supposing that he may have been so.

During the course of early education which he was thus receiving, the boy is said to have been often known to stand angling from a jetty which ran out into the sea, at the back of his father's house on the shore at Greenock; and which thus offered a tempting opportunity for exercise of the gentle, silent, and solitary art. Such pastime, so invitingly presented to his hours of leisure, he must have been either more or less than a boy altogether to have slighted; and we should have been very willing to credit, upon any tolerably circumstantial authority, the further statement that the same recreation was "often resorted to by him even in after-days, when confinement or over-application to study had rendered a slight and temporary relaxation necessary to his constitution," &c.* There would have been something cheerful and agreeable in associating the name of James Watt with those of Dean Nowell, Sir Henry Wotton, and Izaak Walton, Sir Humphry Davy, Dr. Wollaston, Sir Francis Chantrey, and other eminent worthies who have perseveringly followed "the most fitting pastime for quiet men and lovers of peace." But we have no other ground than the general statement above cited, for being able to do so; and there is only too much reason to think that, during by far the greater part of his long and laborious life, Mr. Watt had neither the leisure, nor often the opportunity, nor latterly perhaps the inclination, to amuse himself with that peaceful recreation, to many minds so full of delight, so calmly contemplative, and healthfully active.

However that may have been, there were pursuits which young Watt preferred even to the sports usually most popular with youths of his years. The ill health which at first seemed likely to form an obstacle to his rapid advancement in learning, seems to have had in his case, as in that of many others, only the effect of forming habits of persevering study, and of a disregard of temptations to the indolent loss or frivolous waste of time and thought. "I even think it an advantage to me, and am truly thankful for it," says Dr. Priestley, "that my health received the check that it did when I was young; since a muscular habit from high health, and strong spirits, are not, I think, in general accompanied with that sensibility of mind which is both favourable to piety and to

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* Memorials of Watt, p. 136.

"speculative pursuits."* And to the successful cares of James Watt's homely tuition may in great part be traced not only his habitual industry, and practice of many other humble virtues, but also that neatness in drawing, handwriting, and other manual occupations, together with skill in the computation of numbers, which he was wont to reckon among his favourite accomplishments; as well as that strong love of order which presided over every arrangement, and bestowed on his conversation and thoughts, in an extraordinary degree, all the excellences of a lucid method. Of the advantages of such tastes and habits in ordinary life, all men must be in some degree sensible; and it is needless to dilate on their infinite value in a career such as that which he was destined to pursue.

In witnessing his father's mode of conducting his business, and assisting him in several of its details, he appears to have acquired both good habits of commercial and manufacturing diligence, and many useful rudiments of practical mechanics. The carpenter's benches and tools which that business kept in full occupation, were fraught with instruction to a mind that was already decidedly bending itself towards the study of the mechanical arts; and the frequent completion or restoration of the rigging, fittings, and furniture of a ship,—the sails and ropes, the blocks and tackle, the pumps and capstans, the rudder and compasses,—involved the application of many ingenious resources of a rude sort of natural philosophy, which he was not slow to apprehend and treasure up. He soon learned to construct, with his own hands, several of the articles required in the way of his father's trade, thus gaining a ready familiarity in working with the different kinds of metal, wood, and other materials, and a serviceable knowledge of their comparative qualities. He had a small forge set up for his own use; was fond of repairing and making all sorts of instruments; and did not disdain to form out of a large silver coin, and present to a friend, as a trophy of his early skill as a metal-smith, the *Regium Donum* of a silver punch-ladle.

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* Memoirs of Dr. Priestley, by himself, p. 103, ed. 1806.

His father made and erected, for the use of "the Virginia "tobacco ships," the first Crane ever seen or employed at Greenock; and of that, as of many other useful or curious machines,—(among their number was *a barrel organ*),—small working models were neatly prepared by the young artificer. Even in his extreme old age there were not wanting occasional recollections of the minor, but secret, mysteries of such handicraft, in which he had been initiated when working, "in his shirt-sleeves," in the carpenter's shop:—as when, in his eightieth year, he instructed a certain great bookseller to have his boxes for books *planed on the inside;* or wrote to Sir Henry Raeburn (2nd March, 1816), "I beg to advise your "packer always to rub his wood-screws on some candle-"grease before he screws them in: it will tend much to his "own ease as well as to that of him who unscrews them."

A familiarity with the use and principles of construction of the telescopes, quadrants, and other optical instruments of which his father kept a stock for the supply of ships, was also early acquired by the boy, who always manifested a strong inclination to observe the problems of the physical world around him, and to reflect on their causes. "The prosecution "of his favourite geometry," says Mr. Williamson, in introducing another of those interesting local anecdotes which give its peculiar value to his work, "now occupied habitually his "thoughts and time; and it is not surprising that astronomy "should have become with him a fascinating study. In the "repositories of his father were to be found abundance of "optical instruments of various kinds, calculated to render "his observations of the heavenly bodies both accurate and "enlarged. Of these the young astronomer sedulously availed "himself. . . . To the south of the town, and on the "rising ground behind the church, at no great distance from "his father's house, was a clump of trees of considerable "extent, composed of stately elms and venerable beeches, "part of what were, in former days, the retired and beautiful "pleasure-grounds of the Old Mansion-house of Greenock.

" The planting referred to was, it is much to be regretted, " more than forty years ago, cut down, to make room for questionable improvements; but, before that time, occupying a " height which was on a level with the present Well Park,— " its grey and moss-grown gateways are still standing,—it " formed a back-ground of great beauty to the elevation of " the town when viewed from the sea. Here the young " recluse found a genial retreat. To this spot he was wont " to retire at night as well as by day; and, like another Ferguson, the astronomical herd-boy of Scotland, was known " to spend hours lying upon his back, to watch through the " trees the wondrous movements of the stars." *

A circumstance which, whether we regard it as merely a curious coincidence, or as having perhaps in some degree exercised a prophetic direction over the future destiny of young Watt, must be considered as certainly remarkable, is, that among the few articles of household decoration of which the humble mansion of Thomas Watt and his sons could boast, were portraits of John Napier, the celebrated inventor of logarithms, and of Sir Isaac Newton:—of Napier, "the " person to whom," according to Hume, "the title of Great " Man is more justly due than to any other whom his country " ever produced;" and of Newton, "whose glory it was to " have led the way in sublime discovery, and to have impressed whatever he touched, with the stamp of profound " and original genius." † These paintings, (being, with the exception of some family portraits, which have also been preserved, the only pictorial contents of the house), are not of any very extraordinary pretensions on the score of art; the Newton, in particular, appearing to be a rather indifferent copy of not the best original. But the portrait of Napier is, irrespective of the history of Watt, of high interest, having every appearance of being either an original likeness, or at the least a contemporary copy of a good original, painted with care and fidelity. It is "without the cowl;" therein

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* Memorials of Watt, pp. 137 and 138.

† Sir John Leslie, Treatise on Natural and Chemical Philosophy, p. 58, ed. 1838.

differing from five out of the six portraits described by Mr. Mark Napier, in the preface to the Memoirs of his great ancestor. And it appears to be the *vera effigies* of the sage, in those latest years of his life when snows of age had fallen on his head, and furrows of ancient thought had been ploughed deep upon his brow; when not only had his great work, the 'Mirifici Canonis Logarithmorum Descriptio,' been for some years made public, but even his 'Rhabdologia,' the last of all his works which appeared in his lifetime, was either published, or, at least, completed in its author's mind; for his left hand is represented as resting on a set of those figured implements of calculation, commonly known in his own country as "Neper's Bones." This, indeed, seems to fix the time at which the likeness was made, at a very late hour in the evening of his life; for the date on the title-page of the printed volume containing the 'Rhabdologia,' the 'Promp-'tuary of Multiplication,' and the 'Local Arithmetic,' in which the use of the "Bones" is explained, is 1617, and on the 4th of April in that year he died.

Mr. Napier mentions that at Milliken House, in Renfrewshire, so late as the close of the last century, Colonel Milliken Napier, the lineal male representative of Robert, a younger son, and also the literary executor of the author of the Logarithms, was in possession of many private papers of the family; which, "*along with a portrait of the great Napier*, "and a Bible with his autograph, were deposited for safety "in a room of the house. During the owner's absence the "house was burned to the ground, and the precious relics "perished."* Mr. Napier also mentions that he is unable to trace the history of the other portrait "without the cowl," which is, he says, "a very original-looking half-length," acquired by the late Lord Napier. Possibly one or other of the two "without the cowl" may have been a copy, or *replica*, of the portrait said to have perished in the fire at Milliken; that belonging to Thomas Watt, at all events, inhabited the same county nearly a century before the date of that disaster. But however that may be, the fact of James Watt having been nurtured thus at the feet of those two venerable masters, of his having early and long thus gazed upon the light of their countenances, and imbibed his first acquaintance with their works and fame, as it were, under the sanction of their very presence and eye, is too interesting not to deserve commemoration in the annals of his early days; difficult as it often must be for even the most inquiring minds "to re-" ascend in memory to that which may have given the first " impulse to their entire course of life." *

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* Introduction to Napier's Treatise, 'De Arte Logisticâ,' printed, under Mr. Mark Napier's able editorship, for the Bannatyne and Maitland Clubs, Edinburgh, 1839, p. iv. See also Mr. Napier's Preface to his 'Memoirs of John Napier, of Merchiston,' 1834, p. v.

In precincts hallowed by such Lares and Penates, and not devoid of the "imagines majorum,"—for portraits of Thomas Watt and Margaret Sherrer, as well as of James Watt, sen., of Greenock, and of Agnes Muirheid, then hung on their walls, and are now associated in a family series with those of their more illustrious descendant,—the boy grew to the age of nearly eighteen, a contemplative, yet far from inactive youth. But his ideas were destined to be expanded, and his hopes to be checked, amid increasing reverses of his father's fortunes. So far, indeed, did those reverses at last extend, that it became necessary that both of Mr. Watt's sons, at as early an age as possible, should be trained to rely for their future comfort or distinction, and indeed for their very subsistence, on their own independent and unaided exertions. Of John, the elder of the two lads, we have already spoken, and told how a shipwreck in the Atlantic Ocean removed him from " the waves of this troublesome world."

From the aptitude which James displayed for all kinds of ingenious handiwork, and in accordance with his own deliberate and earnest choice, it was decided that he should proceed to qualify himself for following the trade of a mathematical-instrument-maker;—a career, in which, besides the prospect of turning to good account his habits of industry, his accuracy of eye, and neatness of hand, he doubtless foresaw opportunities,

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* Humboldt's Cosmos, translated by Mrs. Sabine, vol. ii. p. 92, ed. 1849.

such as no other calling within his reach was likely to afford, of gratifying his thirst for the knowledge of physical science.

On the peculiar range of employment to which the main force of his mind was to be directed, he seems, as he grew up, always to have looked with a more than affectionate predilection. The *call*, indeed,—that fixed purpose of soul, declaring itself in action, and leading a man to walk with firmness in a predestined and beloved path,—which made Watt a mechanical philosopher, seems to have been as decided as that which took Burns from the sheepfolds and raised him to be a fervid bard, or transferred Wilkie from the austerities of a Presbyterian manse to become a glowing and triumphant painter. It was such as calls into life every energy, strengthens into devotion every desire, and creates at once the glory and the happiness of all who, like him,—

> ———" Fixing hope and aim
> " On the humanities of peaceful fame,
> " Enter betimes with more than martial fire
> " The generous course: aspire, and still aspire;
> " Upheld by warnings heeded not too late,
> " Stifle the contradictions of their fate,
> " And to one purpose cleave, their Being's godlike mate!" *

With these views he came to Glasgow in June 1754, being then eighteen years of age, and remained under the roof and care of his maternal relations, the Muirheids, till the month of May in the following year. There is still extant a document which bears amusing testimony to the almost primitive simplicity with which his migration from the paternal home was performed. It is entitled, in the clerkly hand of their youthful possessor, "A list of James Watt's clothes taken to "Glasgow;" and, after certain "silk stockings," "ruffled "shirts," and "cut velvet" waistcoats, there follow in it "one working ditto," "one leather apron," "a pair bibels," about a score of the most needful tools of carpentry, and a quadrant. Of all the latter items (with the exception of the "pair bibels," which were, it seems, somehow or other unaccountably left behind!) it will soon be seen that he made dexterous and successful use.

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* Wordsworth's Stanzas to Liberty. Poetical Works, vol. v. p. 102, ed. 1846.

During his stay at that time in Glasgow, young Watt enjoyed the advantage of being introduced to the notice and acquaintance of several of the most learned Professors in the University, through the instrumentality of his mother's kinsman, Mr. George Muirhead, who had then just exchanged the Professorship of Oriental languages for that of Latin, and was associated with his colleague Professor Moor in scholarlike labours which have honourably perpetuated his name.* Professors James Moor and George Muirhead were the joint editors of the magnificent Homer, in four volumes folio, which was printed at the University press by the brothers Robert and Andrew Foulis, in 1756 and 1758; and of which Dr. Harwood says that it is " one of the most splendid editions of " Homer ever delivered to the world, and I am informed that " its accuracy is equal to its magnificence. Since the pub- " lication of the first edition of this work," he adds, " I had " occasion carefully to read through this edition, and I only " discovered two trivial errors." (View of the various editions of the Greek and Roman Classics, with remarks, by Edward Harwood, D.D. 3rd edition. London, 1782.) " As the eye " is the organ of fancy," says Gibbon, " I read Homer with " most pleasure in the Glasgow folio. Through that fine " medium the poet's sense appears more beautiful and trans- " parent. Bishop Lowth has said that he could discover only " one error in that accurate edition—the omission of an iota " subscribed to a dative." In the Life of Winckelmann it is stated that he never travelled without Homer; " his com- " panion at every instant of his life;" and that the edition which he had with him on his last journey (in the course of which he died), " era quella di Foulis, stampata molto ele- " gantemente a Glasgow nel 1756-58." In 1804 a copy of this bibliographical treasure, on large paper, illustrated with Flaxman's plates to the Iliad, and some drawings, by Miss Wilkes, to the Odyssey, sold for 39*l.* 18*s.*

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* Professor George Muirhead's own copy of his great work, *on large paper, uncut*, "a fair and everlasting monu- " ment" of his diligent scholarship, is now by inheritance in the possession of the author; who, for a further brief record of his learned kinsman's life, may refer to the article on "The Muirhead Prizes" in 'Deeds 'instituting Prizes in the University 'of Glasgow;' 4to. Glasgow, 1850, pp. 201-206.

Watt, however, was not so fortunate as to become the pupil of any Professor in the ancient University, which the talents of men such as Adam Smith and Robert Simson then so greatly adorned; and the youthful student has himself recorded that he never attended any course of lectures delivered within the walls, or by the teachers, of the College. But he at once gained the favourable notice of Dr. Dick, who was joint Professor of Natural Philosophy with his father from 1751 to 1757, to whose society the subjects of his pursuits formed an immediate attraction, and of whose abilities, as well as of the kind interest he manifested in his success, Mr. Watt always spoke in terms of the most grateful praise. Dr. Dick having observed the qualifications of his young friend, and being consulted as to his outset in life, strongly recommended his proceeding to London, to acquire better instruction in the art which he designed to practise, than could at that time be gained in Glasgow, or, indeed, anywhere in Scotland; at the same time furnishing him with a personal introduction which proved very serviceable in obtaining for him the advantage of such tuition.

It being then arranged that young Watt should follow this counsel, on the 7th of June, 1755, he set out for the great metropolis, in charge of his connection Mr. John Marr,* who, we believe, afterwards became the captain of an East Indiaman, but soon after their arrival in London accepted the office of naval instructor on board the Hampton Court, a seventy gun ship, then lying at anchor in the Thames. They travelled, as was common a century ago, on horseback, riding the same horses throughout the journey, which they performed in twelve days, including two of partial or entire rest. "There was, in the days of which I write," says Sir Walter Scott, "an old-fashioned custom on the "English road, which I suspect is now obsolete, or prac-

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* Mr. Marr's wife was a cousin-german of Mr. Watt.

" tised only by the vulgar. Journeys of length being made " on horseback, and, of course, by brief stages, it was usual " always to make a halt on the Sunday in some town where " the traveller might attend Divine service, and his horse " have the benefit of the day of rest, the institution of which " is as humane to our brute labourers as profitable to our- " selves."[*] Their route was by Coldstream, Newcastle, Durham, York, Doncaster, Newark, and Biggleswade; and the principal note made by the young traveller in the new scenes through which he now passed, is a laconic one:— " I like the country very [well], *but think the people are* " *very sharp.*" It must be added, in explanation of this concise and "canny" conclusion, that nearly one-third of the time occupied on the road was spent in riding through *Yorkshire;* in fact, the letter which contains it[†] was written *at York!*

On their arrival in London no time was lost in endeavouring to find a fitting instructor in the mathematical-instrument line,—a task which at first appeared likely to prove one of unexpected difficulty; for the number of masters skilled in that scientific trade was then small, and it was "the custom " of London" not to dispense with the regular apprenticeship of seven years on indenture. " I have not yet got a master; " we have tried several; they all make some objection or " other," writes the poor lad. " I find that if any of them " agree with me at all, it will not be for less than a year; and " even at that time [they] will be expecting some money."[‡] Having been nurtured in the observance of rigid frugality, and being most dutifully anxious to avoid all encroachment on his father's means, which seem to have diminished in an inverse ratio to his own necessities, his narrow finances were now a cause of uncomfortable apprehension; and altogether his early impressions of life in London were very far from being either joyous or encouraging.

But by degrees a little light began to dawn above the dim horizon. "Yesterday," writes Mr. Marr to Mr. Watt, sen., at Greenock,* "your son began to divert himself in cutting "letters and figures, &c., in the shop of Mr. Neale, watch-"maker, from whom I had the small patent globes. Mr. "Neale is the frankest tradesman of any of the fraternity I "have seen. . . . In the meantime I shall endeavour to "see him employed at Mr. Neale's, who inclines to have "some of his work to show." His specimens having been approved of, we find him, by the first week of July, through the exertions of Mr. Short, (a valuable friend whom Dr. Dick's recommendation had procured him), at work on the brass part of Hadley's quadrants, with Mr. John Morgan, mathematical-instrument-maker in Finch Lane, Cornhill,—"a man," soon afterwards writes his youthful disciple, "of as good a cha-"racter, both for accuracy in his business and good morals, "as any in his way in London. Though he works chiefly in "the brass way, yet he can teach me most branches of the "business, such as rules, scales, quadrants, &c." † "Within "the bills of mortality," adds Marr, "he could not have "found a man better recommended for good nature and in-"genuity than Morgan." ‡ And, "If it had not been for "Mr. Short," writes the lad, "I could not have got a man in "London that would have undertaken to teach me, as I now "find there are not above five or six that could have taught "me all I wanted." §

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[*] Sir W. Scott, ROB ROY, chap. iv., Abbotsford edition, vol. iii. p. 59.

[†] Mr. Watt to his father, York, 12 June, 1755.

[‡] Mr. Watt to his father, London, 1 July, 1755.

An agreement was soon concluded, with the approbation of Mr. Watt, sen., for his son receiving a year's instruction from Mr. Morgan, for which he was in return to pay twenty guineas, and give his labour for that period in the business. After this his progress was rapid and steady. By the 5th of August, he had made a brass parallel ruler 18 inches long, and a brass scale of the same length, and was about to finish some of Hadley's quadrants; by the 23rd of that month, he had done a Hadley's quadrant better than his master's apprentice, " who had been two years with him." " Very few " here," he says, " know any more than how to make a rule, " others a pair of dividers, and such like, which they serve a " seven years' apprenticeship to." In October he had begun to make rules, which it was then a most difficult matter to get good, " there being only one man who could make them " perfectly well, and he having lately taken to other work." In November he was busy with azimuth compasses; by December, 1755, he " could work tolerably well;" and expected that by April he would understand so much of his business as to be able to work for himself, or to be an assistant to his father. When April arrived he was to make a brass sector, a theodolite, and some other instruments of the better sort; " and then," he writes, " I think I shall be " able to get my bread anywhere, as I am now able to work " as well as most journeymen, though I am not so quick " as many." * And when his year's toil was completed, and the " leafy month of June " had again come round, he announced, with some reasonable pride, that he could now make " a brass sector with a French joint, which " is reckoned as nice a piece of framing work as is in the " trade." †

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* Mr. Marr to Mr. Watt, senior, London, 24 June, 1755.

† Mr. Watt to his father, London, July 21st, 1755.

‡ Mr. Marr to Mr. Watt, senior, London, Aug. 6th, 1755.

§ Mr. Watt to his father, London, Sept. 2nd, 1755.

But all this early expertness was not acquired for nothing; it cost him a constant and hard struggle to reach that step on the upward ladder; and his labours were rendered the more severe by the state of his health, from which he had of late greatly suffered. He had not only, as was his wont, led a life of the most regular and unremitting industry, and spared no exertion by which he might diminish to his father the cost of this part of his education, but his endeavours to attain that end were accompanied by a rigid self-denial on which, however in itself exemplary and laudable, it is almost painful to reflect. Lodging, it is believed, under the roof of his master, but not receiving from him any of his board, the cost of his food was in all but eight shillings a-week; lower than that,

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* Mr. Watt to his father, London, April 20th, 1756.

† Mr. Watt to his father, London, June 19th, 1756.

he writes, he could not reduce it, "*without pinching his belly.*" Even of that pittance a great portion was earned by himself; for he found that he was able to "win" some money on his own account by rising still earlier than he had to go to his master's work. The bread so bought must have tasted sweet indeed to his lips; but at night he was thankful enough to get to bed "with his body wearied, and his hand shaking, "from ten hours' hard work;" "we work," he says, "to nine "o'clock every night, except Saturdays." In his letters to his home, while describing the frugality of his way of life, and regretting the charge his living must be to his father, on whom he fervently prays that the blessing of God may rest, he repeatedly adds that he is striving all he can to improve himself, that he may be the sooner able to assist him, and to ensure his own maintenance.

With such motives to exertion, and such sentiments and habits, it will readily be conceived that he considered his year in London as admitting of no holiday indulgence. So earnestly was he bent on self-improvement in the way of his business, and so entirely were his whole time and strength engaged in the constant exertion which that required, that only on two occasions,—the arrival of the King from abroad, and a proclamation of war against France,—does the uniformity of his industry appear to have been diversified, even by the sight of such pageants as every metropolis from time to time affords to the eyes of the poorest of its inhabitants. Indeed, so far was he from allowing any occupation of his time in even receiving or giving the news of the day, that the only allusion which his letters of that period contain relative to such subjects is the emphatic and summary conclusion, that "*as for news, there is no believing anything that* "*is said;*"—a maxim which, in other days than his, may still perhaps be deemed not altogether devoid of salutary truth!

An unexpected danger at that time hung over his destiny, which might have cut short, at least for a season, his projects of further improvement in natural science, and postponed *sine die* his return to Glasgow College, with all its interesting consequences. This sword of Damocles was the chance of being impressed as a seaman for the navy. He writes, in the spring of 1756, that he avoids "a very hot press just now "by seldom going out." And on a later day he adds, "they "now press anybody they can get, landsmen as well as seamen, except it be in the liberties of the City, where they "are obliged to carry them before my Lord Mayor first; "and unless one be either a 'prentice or a creditable tradesman, there is scarce any getting off again. And if I was "carried before my Lord Mayor, I durst not avow that I "wrought in the City, it being against their laws for any "unfreeman to work, even as a journeyman, within the "Liberties." *

At the close of his engagement with Mr. Morgan, when he "had no doubt he could have got encouragement from either "his master or some other,"—after long contending with the badness of his health,—he found himself compelled by "violent rheumatism," "a gnawing pain in his back," and "weariness all over his body," to seek the benefit which he expected to derive from his native air, and the ride homewards. So, in the end of August, 1756, he took leave of London and of Mr. Morgan, (who, dying in 1758, was not destined to witness the future success of his pupil), and to revive his drooping health and spirits, he returned to his own country and friends;—first, however, making a small investment of about twenty guineas in half a hundred additional tools, with "absolute necessary" materials for "a great many more that "he knew he must make himself," together with a copy of 'Bion's Construction and Use of Mathematical Instruments,'—a copious and useful treatise on the different branches of his intended trade. This was the first edition of the translation of M. Bion's work, by Edward Stone, an excellent, though self-taught, mathematician, a native of Scotland; it was a great enlargement of the original, and two editions of it were subsequently published in folio, bearing the dates of 1758 and 1759, together with a supplement, from which we learn that the first impression had been soon sold off, and a second long called for by the booksellers and the public. The original treatise in French was a small one in quarto, published at Paris in 1752, and its price was only a few francs.

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* Mr. Watt to his father, London, March 31st, 1756.

CHAPTER V.

MR. WATT'S EMPLOYMENT BY THE COLLEGE OF GLASGOW — HIS ESTABLISHMENT WITHIN ITS WALLS AS MATHEMATICAL-INSTRUMENT-MAKER TO THE UNIVERSITY — PROGRESS IN HIS BUSINESS — SHOP-KEEPING — HIS CONSTRUCTION OF ORGANS AND OTHER MUSICAL INSTRUMENTS — INSTRUMENTS OF HIS MANUFACTURE STILL IN EXISTENCE — CHANGE OF ABODE — HIS MARRIAGE — MACHINE FOR DRAWING IN PERSPECTIVE.

AN occasion soon presented itself for the advantageous employment of that little stock in trade which we have just described, as well as of the newly-acquired skill of its owner. On the 25th of October, 1756, he writes from Glasgow to his father:—"I would have come down [to Greenock] to-"day, but that there are some instruments that are come "from Jamaica that Dr. Dick desired that I would help to "unpack, which are expected to-day." The instruments here spoken of formed a valuable collection, which had been completed at great cost by the best makers in London, for their late proprietor Mr. Alexander Macfarlane, a merchant, long resident in Jamaica, and a cadet of the ancient feudal house of Macfarlane of that Ilk; who seems, amid his mercantile pursuits, not to have forgotten the motto of his family—"*Astra castra, Numen lumen;*"—"*The stars my* "*camp, the Lord my light;*"—and who, dying in 1755, bequeathed the contents of his observatory to the University in which he had received his education. The great astronomer Oltmanns, the companion of Humboldt, in mentioning, among some observations from which various latitudes and longitudes in the West Indies were accurately determined, those which Mr. Macfarlane had made, at Port Royal, near Kingston, Jamaica, (Phil. Trans. for 1723, p. 235, and for 1750, p. 523), has said:—"Macfarlane was provided with "excellent English instruments, and very skilful in the

" theory and practice of astronomy."* An account of certain curious lunar observations of another sort, made by the Clan Macfarlane in earlier times, but of which the learned and worthy merchant of Port Royal was of course guiltless, is given in Sir Walter Scott's note on *Mac-Farlane's buat, or lantern*, in 'Waverley,' chapter xxxviii., where he says, " The clan of " Mac-Farlane, occupying the fastnesses of the western side " of Loch Lomond, were great depredators on the Low " Country; and, as their excursions were made usually by " night, the moon was proverbially called their lantern. Their " celebrated pibroch of *Hoggil nam bo*, which is the name of " their gathering-tune, intimates similar practices," &c.† The minute of a University meeting on the 26th of October, bears that " Several of the instruments from Jamaica having " suffered by the sea-air, especially those made of iron, Mr. " Watt, who is well skilled in what relates to the cleaning " and preserving of them, being accidentally in town, Mr. " Moor and Dr. Dick are appointed to desire him to stay " some time in town to clean them, and put them in the best " order for preserving them from being spoiled." On the 2nd of December the same records bear that " a precept was signed " to pay James Watt five pounds sterling for cleaning and " refitting the instruments lately come from Jamaica ;"—this being, in all probability, the first money he had earned on his own account since the termination of his brief apprenticeship.

His next object was to endeavour to establish himself in the way of his trade in the city of Glasgow; but here he was met by obstacles of the same sort as those which in London had first well-nigh excluded him from the brief instruction which he sought, and then might have consigned him, without hope of rescue, to the embraces of the pressgang. Neither being the son of a burgess, nor having, as yet, married the daughter of one, nor having served a regular apprenticeship to a *craft*, he was visited, by tradesmen of more arrogant and far more unfounded pretensions than the modest youth whom they persecuted, with a sort of temporal excommunication; and was forbidden to set up even a humble workshop, himself its solitary tenant, within the limits of the burgh. He now signally found the advantage of that academical support which the University uniformly extended to him. By midsummer, 1757, he had received permission to occupy an apartment and open a shop within the precincts of the College, and to use the designation of "Mathematical-instrument-maker to the "University;" and, though it does not appear that any contemporaneous record has been preserved in the archives of the University of the date of the workshop having been assigned to him, on the 27th of November, 1759, directions were given for having "the room above Mr. Watt's workshop" repaired.* In the autumn of 1757, the foundation-stone of an astronomical observatory, to receive the collection of instruments which he had repaired and set up, and to be called the Macfarlane Observatory, was laid, he being then twenty-one years of age. At the same time, however, he had the sorrow and misfortune to lose his able and true friend, Dr. Dick; and the result, in a pecuniary point of view, of this first year of his business, was very far from being a hopeful one.

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* 'Recueil d'Observations Astronomiques, Voyage de Humboldt et Bonpland,' Quatrième Partie, tome ii., p. 589, ed. 1810.

† Abbotsford edition, vol. i. p. 213.

On the 15th September, 1758, (the year in which his old master, Morgan, died), he thus writes from Glasgow to his father:—"As I have now had a year's trial here, I am able "to form a judgment of what may be made of this business, "and find that unless it be the Hadley's instruments, there is "little to be got by it, as at most other jobs I am obliged to "do the most of them myself; and as it is impossible for one "person to be expert at everything, they very often cost me "more time than they should do. However, if there could "be a ready sale procured for Hadley's quadrants, I could do "very well, as I and one lad can finish three in a week easily; "and selling them at 28*s.* 6*d.*, which is vastly below what "they were ever sold at before, I have 40*s.* clear on the

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* See 'Deeds instituting Bursaries, Scholarships, and other 'Foundations in the College and 'University of Glasgow,' 1850: 4to., p. 215.

“ three. So it will be absolutely necessary that I take a trip “ to Liverpool to look for customers, and hope that upon the “ profits of what I shall be able to sell there, I can go to “ London in the spring, when I make no doubt of selling “ more than I can get made; all which I want your advice “ on. And if that does not succeed, I must fall into some “ other way of business, as this will not do in its present “ situation.” The sale, however, of the profitable Hadley's instruments appears to have increased at home so much, as to have rendered the proposed speculative trading voyage to Liverpool unnecessary.

From the advertisement already referred to, dated October 22, 1759, of the engraved map of the river Clyde, as “to “ be sold by James Watt, at his shop in the College of “ Glasgow,” as well as from the entry in the College records of the repairs to be done in “the room above Mr. Watt's “ workshop,” we know that, up to that time at least, he continued to use the shelter of the academic walls for the purposes of his trade. By the 7th of October in that year, he appears to have entered into a sort of partnership with a Mr. John Craig, to carry on and extend the business in which he was engaged, continuing to occupy his rooms and workshop in the College till 1763.

A Journal of the partnership concern, kept from October, 1759, till April, 1765, commences with the following entry:— “ An Inventory of Tools, Goods, &c., belonging to us, James “ Watt and John Craig, each one-half. Taken Oct. 7th, 1759, “ at Glasgow;” and then enumerates a variety of mechanical tools, from a turning-lathe to a flatting-mill; with philosophical instruments, chiefly mathematical and optical, from the familiar “Hadley's quadrants” to microscopes and sea-

compasses; the whole to the value of . .	£91	19	3½
Which, with “cash on hand,” . .	108	0	8½
Made the little stock in trade amount to	£200	0	0

A small but steadily increasing traffic brought the “ready- “ money sales,” towards the end of the period over which the Journal extends, up to about 50*l.* per month, or 600*l.* per annum; a large portion of which, however, must have gone to pay for materials and the wages of workmen. James Watt is throughout credited with a salary of 35*l.* per annum; Craig appearing to have taken no share in the manufacturing part of the business, but only, (as is shown by a memorandum in the Journal), to have been book-keeper to the concern, and to have advanced the greater portion of the requisite funds. One journeyman throughout the year, and three or four others, from time to time, as occasion required, were all that Mr. Watt at first found it necessary to employ; but before the end of 1764 their number had increased to sixteen "of "all arms." Among their names we find those of three Gardners,—Alexander, David, and John,—of whom one at least was long afterwards known in Glasgow as a well-instructed and reputable philosophical-instrument-maker. From the accounts of the business coming to a close in 1765, and Mr. Watt having said in a letter to Mr. Boulton in 1768, "about three years ago, a gentleman who was concerned with "me died," we conclude that the termination of the partnership is thus explained.

In the retired course of life which, from choice as well as necessity, he appears to have followed, manual labour and mental study were blended in pretty equal proportions; but idleness or mere amusement had certainly no share. He ardently seized every opportunity of extending his acquaintance with the various branches of physical philosophy, and of investigating the principles of its phenomena, as if prophetically conscious that to his untaught but earnest apprehension might be revealed those secrets which hitherto had been hidden even from the wise and learned; endeavouring,—to use an expression of his own,—"to find out the weak side of "Nature, and to vanquish her,"—"for Nature," he again says, "has a weak side, if we can only find it out!" Beyond the necessity for some daily labour in order to earn his daily bread, and his hope,—often, as will be seen, very uncertain,—of future independence, he had little else than the pleasure he found in philosophical pursuits to stimulate or reward his zeal: the toils of his business were severe, and the profitable returns but small; while of those whose society was open to him, there were few indeed who possessed either an equality of learning or a community of tastes with himself. But in his endeavours to subjugate, by the resources of practical art, those natural difficulties which presented themselves to his hand or eye, nothing seemed to deter his zeal or baffle his penetration; a very curious proof of which was afforded by his frequent construction, about the period at which we have now arrived, of musical instruments of perfect compass and tone, although he had himself, by nature, an absolute deficiency of all musical ear.

Professor Robison, in a document from which we shall hereafter have to make large quotations, gives a remarkable instance of this:—"A mason-lodge in Glasgow wanted an "organ. The office-bearers were acquaintances of Mr. Watt. "We imagined that Mr. Watt could do anything; and, "though we all knew that he did not know one musical "note from another, he was asked if he could build this organ. "He had repaired one, and it had amused him. He said, "'Yes;' but he began by building a very small one for his "intimate friend Dr. Black, which is now in my possession. "In doing this, a thousand things occurred to him which "no organ-builder ever dreamed of,—nice indicators of the "strength of the blast, regulators of it, &c. &c. He began to "the great one. He then began to study the philosophical "theory of music. Fortunately for me, no book was at hand "but the most refined of all, and the only one that can be "said to contain any theory at all,—Smith's Harmonics. "Before Mr. Watt had half finished this organ, he and I "were completely masters of that most refined and beautiful "theory of the beats of imperfect consonances. He found "that by these beats it would be possible for him, totally "ignorant of music, to tune this organ according to any "system of temperament; and he did so, to the delight and "astonishment of our best performers. In prosecution of "this, he invented a real monochord of continued tone; and, "in playing with this, he made an observation which, had it

" then been known, would have terminated a dispute between " the first mathematicians in Europe,—Euler and D'Alem- " bert; which completely establishes the theory of Daniel " Bernouilli, who differed from both of those gentlemen, about " the mechanism of the vibration of musical chords; and as " completely explains the harmonic notes which accompany " all full musical notes, overturning the theories of Rameau " and Tartini."

The date of the construction of those organs is pretty exactly fixed by two letters from his friend Alexander Cumming, F.R.S., a very ingenious adept in similar pursuits, then resident in London, whose name is well known by his meritorious publications on subjects of mechanical interest; such as, the elements of clock and watch-work, the influence of gravitation as a mechanical power, and the effects of cylindrical instead of conical carriage-wheels. Writing to Mr. Watt on the 27th December, 1761, Mr. Cumming approves of his scheme for an organ, supplies him with a note of the prices of organ-pipes, and inquires "How gets on fiddle- " making?" And on the 8th September, 1762, he expresses himself as "glad of his success in organ-building," and describes the magnificent instrument of the same kind which he had himself constructed for Lord Bute, at a cost of 2000*l.* Mr. Cumming adds this further notice of his own proceedings in the way of ingenious musical mechanism:—"I have pro- " posed an improvement on the musical-glasses, (that are " played by moving the wet fingers along the brim), by " making them play with keys; but, as I have as great a " demand in the way of my business as I can well answer, " have put off the thoughts of that and some other experi- " ments till I have more leisure." The organs here spoken of, were not the only produce of Mr. Watt's musical manufacture; and guitars, flutes, and violins are still in existence, preserved with care by their respective possessors, as curious instances of so extraordinary a parentage; which, indeed, when we consider the co-existence of a physical deficiency in a point apparently essential, must be viewed as little short of a miracle in the works of untutored handicraft.

This singular result was brought about in a way very characteristic of the age of which we are speaking: for, a century later, the same opportunity would not have occurred, nor would the same inventiveness have been thereby stimulated. The youth who could not only safely handle and rightly use, but could even restore or construct the complex and mysterious instruments which puzzled the students and attracted the professors of Glasgow College, was naturally looked upon as an oracle. He was visited and consulted on many occasions;—

> "And still they gazed, and still the wonder grew,
> "That one small head could carry all he knew."

And so it came to pass, in days when neat-handed and skilful workmen in any of the nicer handicrafts were rarely to be met with in provincial towns,—when barbers were often surgeons, and blacksmiths, on occasion, could be dentists,—that the maker of the instruments of "Divine Philosophy," was solicited to become a mender of instruments of music. Succeeding beyond expectation in his first attempts in that novel line, it is wonderful how many dumb flutes and gouty harps, dislocated violins and fractured guitars, nervous viol-di-gambas, hysterical mandolins, and thorough-basses suffering from hoarseness, came thenceforward to be cured by him of their complaints, and restored to health and harmony.

It might have been supposed that they could scarcely have gone to a worse doctor; as mere neatness of hand, devoid of all ear for musical notes, could not reasonably have been expected to suffice for the successful treatment of such patients. Yet, from the rapid increase in the extent of that peculiar department of his business, it seems certain that the cures he wrought were very complete and satisfactory; and, as "P. P., clerk of this parish," did unto shoes, so did the young philosopher, with as little derogation from the dignity of his higher calling, unto the instruments of music:—"fiddles "also did he make, and, if entreated, mend; with good "approbation."

Of one of the organs constructed by Mr. Watt, the late

Mr. Archibald Maclellan, who, for thirty years prior to his decease in 1854, was a prominent member of the Town Council of Glasgow, and a zealous patron of the fine arts, became the possessor. In his last illness, Mr. Maclellan dictated the following *historiette*, which is not without interest; although the assertion with which it sets out, of Mr. Watt's fondness for music, needs, as we have seen, very great qualification, and might better have been limited to the predilection, which he no doubt did possess, for constructing musical instruments.

" Mugdock Castle, 14 Sept. 1854.

" It is well known that the great James Watt was fond of " music, and while in Glasgow constructed more than one " organ. One of these was a small instrument, about three " feet square, in the form of a small table, but having externally no appearance of a musical instrument. At this table, " where his friends and he were sitting, the movement being " concealed, Mr. Watt astonished them by the production of " the music. This little table, about forty years ago, fell into " the hands of the late Steven, the music-seller, in Wilson " Street, who had an organ front with gilt pipes and sides " placed on the top of the table, and gave it the shape it " now bears. I bought it from Steven, and put an additional " reed stop into it. It remains so at present. Such is the " history of this interesting little instrument, and I think I " need scarcely recommend it to my trustees as a fancy and a " work of the great James Watt deserving of their notice and " preservation. The instrument, when in proper tune, is of " considerable power and very pleasing harmony, and, in my " keeping, has been orthodox in its application, from 'Martyrs' " to 'Old Hundred.'

" ARCHD. M'LELLAN."

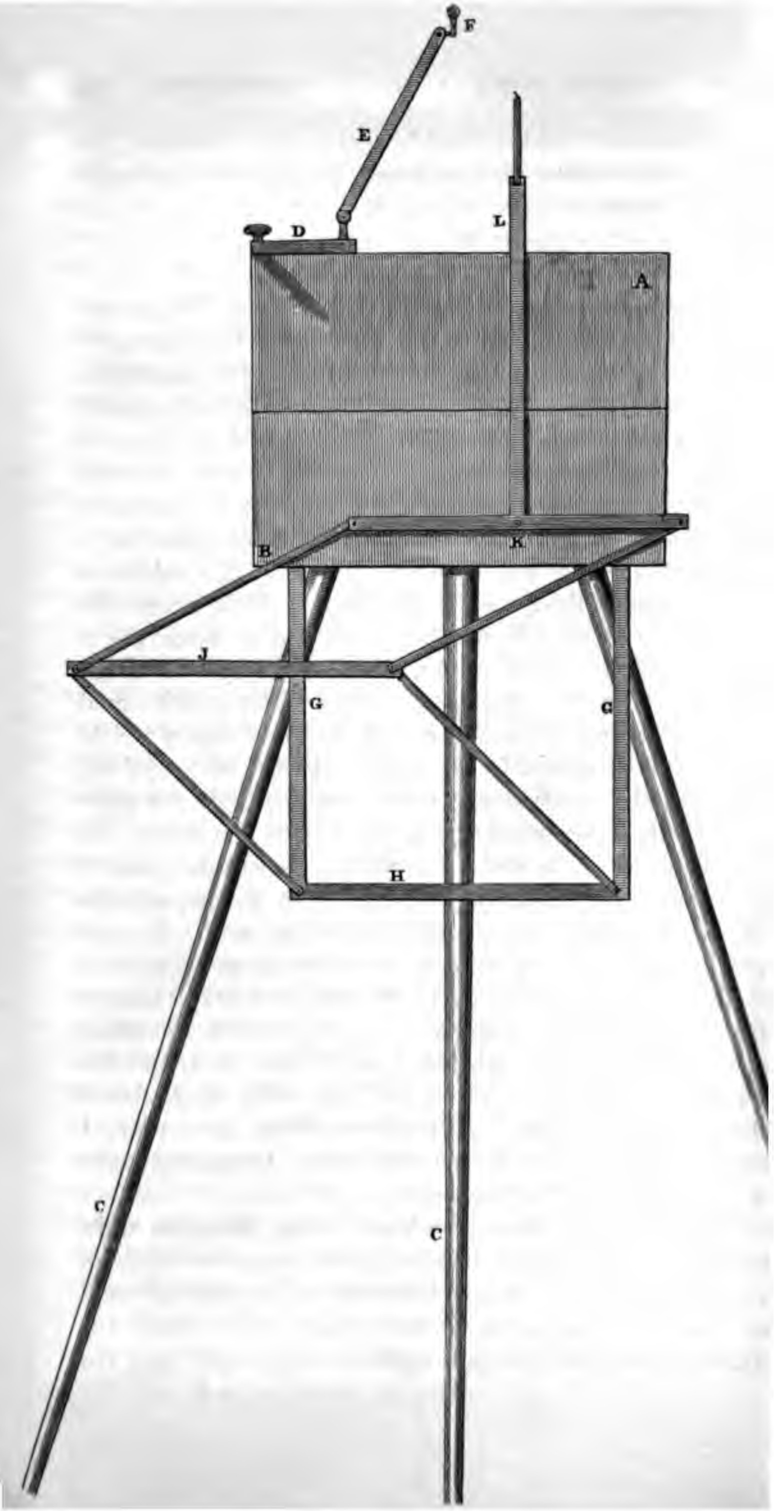
In 1763, Watt quitted his college rooms for a small abode in the city; a change made, probably, in contemplation of his marriage to his cousin, Miss Miller, which took place in July of the following year. The site of his new dwelling, or at least of the workshop in which his earliest experiments on the steam-engine were made, and which in all probability was under the same roof, is stated by Mr. Robert Hart to have been in or close to King Street. " In answer to my question " about the site of this shop, Mr. Watt said, 'It was in a little " 'court [at the] north end of the beef market; the house " 'projects into the court; I think a carrier occupies it at " 'present.' I think this was in the year 1813 or 1814. " My brother and I went next morning, and saw the house; " a large door had been made in the end of it, to make it " into a cart-house, and a carrier was loading his cart in it " at the time. I think it stood where Millar's Place is, " just in front of what was the inn door, as it was but a few " yards from the north-east corner of the market, in a north-" east direction." In 1770 it appears that he went through the " disagreeable operation" of removing his " household furni-" ture and utensils to another house;" but, during the whole of his residence in Glasgow, he practised housekeeping, from necessity as well as choice, on a very humble scale. After his marriage, however, his dwelling was enlightened by a charming presence, which " made a sunshine in that shady " place." " I have not entered," says Miss Campbell, " into " any of the interesting details my mother gave me of Mr. " Watt's early and constant attachment to his cousin Miss " Miller; but she ever considered it as having added to his " enjoyment of life, and as having had the most beneficial " influence on his character. Even his powerful mind sank " occasionally into misanthropic gloom, from the pressure of " long-continued nervous head-aches, and repeated disappoint-" ments in his hopes of success in life. Mrs. Watt, from her " sweetness of temper, and lively, cheerful disposition, had " power to win him from every wayward fancy; to rouse and " animate him to active exertion. She drew out all his gentle " virtues, his native benevolence, and warm affections."

In 1765, Mr. Watt contrived an ingenious machine for drawing in perspective, of which he has left the following description, together with drawings which are here engraved on wood (see pages 52, 53); and the instrument may be considered a sort of connecting link between his mathematical-instrument-making and his surveying. His first perspective machine, like his first organ, was constructed for his friend Dr. Black.

Perspective Machine.

"The perspective machine was invented about 1765, on the "following occasion. My friend, Dr. James Lind, brought "from India a machine, invented by some English gentleman "there,—I believe, a Mr. Hurst,—which consisted of a board, "fixed on three legs perpendicularly, upon which, close to "the bottom and near the ends, were fixed two small friction-"wheels, upon which a horizontal ruler rested, and could be "moved endways horizontally, and this ruler was about twice "the length of the board. On the middle of this ruler was "fixed a perpendicular ruler, reaching a little above the "upper edge of the board, and in this ruler there was a "groove similar to that of the slip of a sliding rule, which "was also, like that, furnished with a slider which could "freely move up and down in it, and the upper end of which, "being pointed, served for an index. In the bottom of the "groove in the perpendicular ruler there was a slit cut quite "through the ruler, nearly from one end to the other. In "the lower end of the slider was fixed a pencil, the point of "which reached quite through the ruler to the paper to be "drawn upon, which was stretched upon the board. An arm "projecting forward was fixed to one of the upper corners of "the board, (I do not remember how), and upon its end nearest "the draughtsman it carried a sight or eye-piece, consisting "of a small piece of metal with a small hole in it, and this "eye-piece was elevated about half the width of the board "above its upper edge. The rulers, sliders, &c., were, I "think, made of brass, consequently heavy; but moved easily "on the pulleys, or friction-wheels.

"In using the machine, the board being placed at right "angles to a line supposed to be drawn from the middle of "the object which was to be delineated, and the sight adjusted "so as to give a proper scale, the socket of the pencil was "taken in the hand, the eye applied to the sight, and the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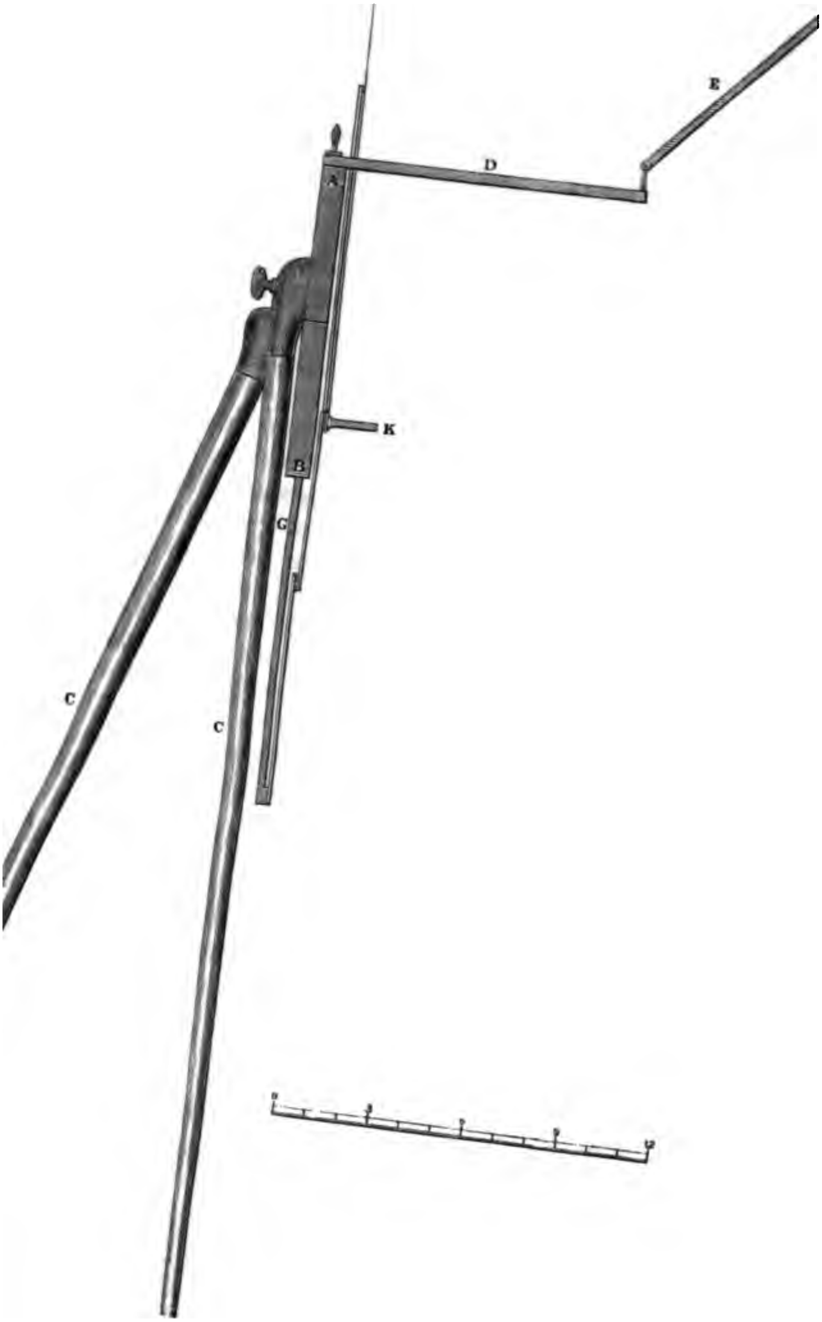
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" index or acute top of the slider was made to travel over the " lines of the object to be delineated, which it was enabled to " do by a composition of the horizontal motion of the lower " ruler on the wheels, and of the perpendicular motion of the " slider in the upright ruler: the pencil then described the " lines upon the paper. This instrument very readily described " perpendicular or horizontal lines, as these accorded best " with its natural motions. But in diagonal or curved lines " it was difficult to make the index follow them exactly, and " the whole motions were heavy and embarrassing to the " hand. Moreover, the instrument was heavy and too bulky.

" I wished to make a machine more portable, and easier " in its use; and, at the suggestion of my friend, Mr. John " Robison, I turned my thoughts to the double parallel ruler, " an instrument then very little known, and not at all used " that I know of. After some meditation, I contrived the " means of applying it to this purpose, and of making the " machine extremely light and portable.

" The machine consisted of a box about an inch and a half " deep on the outside, thirteen inches long, and five inches " wide, and hinged so that when opened it formed a flat " board (AB) of thirteen inches long and ten inches wide, on " which the paper was stretched. It was kept open by means " of three legs (CCC), which were fastened to the back part " of it, and served to support it at a proper height. From " the right hand upper corner of this box or board, a jointed " arm (DE) projected forward, to carry the eye-piece or sight " (F), which could, by means of the joints, be adjusted higher " or lower, nearer to, or further from the board, as might be " required. To the lower edge of the board were attached " two thin slips of wood (GG), ten inches long and ten inches " apart, and to the lower ends of these slips was attached the " lower side of a double parallel ruler (HJK), every member " of which was ten inches long between centres, so that, when " fully open, it formed two squares joined by one side of each, " and in other states formed lozenges, or rhombuses of different " degrees of obliquity. This double parallelogram was formed " partly of thin slips of wood, and partly of brass much

" hammer-hardened, and all very light. To the middle (K) " of the upper side of the higher parallelogram, was fixed, at " right angles upwards, another slip of wood (L), about eleven " inches long, and ending in a brass point which served for " an index, which, by the construction, could be moved equally " easily in every direction, and with very little friction; and, " at the same time, all the positions of the rulers were always " parallel to each other. A pencil, pressed upon by a spring, " was fixed in the junction of the perpendicular slip or index " at K.

" A paper being stretched upon the board, and the sight " being moved to a proper distance from the board, (generally " about eighteen inches), the hand being applied to the pencil " socket, (for the pencil was not pressed upon by the hand), " the upper point of the index was led along the lines of the " objects intended to be delineated; and, when perpendicular " lines occurred, the index pointing to the upper end of them, " the finger of the left hand being applied to the board " touching the perpendicular slip, and the pencil drawn downwards, the line would be straight. In the same way, the " horizontal slip served as a guide for horizontal lines; all " others were drawn by the eye guiding the index, and, if the " paper was smooth, could be drawn very correctly.

" The whole of the double parallelogram and its attached " slips, (which latter were contrived to be easily separated " from the board), were made capable of being readily folded " up, so as to occupy only a small space in the box formed " by the board, when folded up. The sight-piece also folded " up, and readily found its place in the box, which also contained screws for fixing on the legs of the instrument; and " the box, when shut, could be put into a great-coat pocket. " The three legs were made of tinned iron, tapering, and one " a little smaller than another, so that they went into one " another, and formed a walking-stick about four and a half " feet long.

" I made many of these instruments about the time mentioned,—perhaps from fifty to eighty. They went to various " parts of the world: among other places several went to

"London, where George Adams, senr., copied and made them "for sale, putting his own name on them; and, *as I have "been told*, in a book which he published, describing various "instruments, he took the credit of the invention to himself, "or expressed himself so as to leave that supposable: but I "have not seen the book as far as I can remember, but have "seen the instruments with his name on them."

The work here alluded to is doubtless 'A Treatise describing and explaining the Construction and Use of new 'Celestial and Terrestrial Globes, &c. By George Adams, 'Mathematical Instrument maker to his Majesty. London, '1766;' prefixed to which, and bound up with it, is 'A 'Catalogue of Mathematical, Philosophical, and Optical Instruments made and sold by George Adams, Mathematical 'Instrument maker to the King, at his shop, the sign of 'Tycho Brahe's Head, in Fleet Street, London, where Gentlemen and Ladies may be supplied with *such Instruments 'as are either invented or improved by himself*, and constructed 'according to the most perfect theory.' And among the optical instruments is placed—

> "A *new* instrument for taking perspective views .. £6 6 0."

This, when taken in connection with Mr. Watt having seen the instruments with Adams's name on them, and identified them with those of his own invention, certainly seems to warrant the information he received on the subject. Although, perhaps, the first instance, it was to be by no means the last in which he was to suffer by the application of the "*vos non* "*vobis*" principle. But it was usual with him not to make any public reclamation of even his best-established rights, until forced to do so by a strong pressure; and then it was only in the most modest, cautious, and unobtrusive manner.

CHAPTER VI.

MR. WATT'S INTRODUCTION TO DR. BLACK, AND TO PROFESSOR ROBISON — DR. BLACK'S HISTORY OF THEIR FRIENDSHIP, AND OF MR. WATT'S IMPROVEMENTS ON THE STEAM-ENGINE — DR. ROBISON'S HISTORY OF HIS ACQUAINTANCE WITH MR. WATT — ACCOUNT OF HIS CHARACTER, ABILITIES, DISPOSITIONS, HABITS, AND PURSUITS — EXPERIMENTS ON MODEL OF NEWCOMEN'S ENGINE — INVENTION OF SEPARATE CONDENSER, AND FURTHER IMPROVEMENTS ON THE STEAM-ENGINE.

It was at this time that the young artificer's earnest devotion to philosophical pursuits, as well as his amiable and virtuous dispositions, gained him the approving notice and enduring friendship of Dr. Black; who, in 1756, was appointed Professor of Anatomy, and, in 1757, Professor of the Practice of Medicine, in Glasgow College. It was also in the commencement of the winter of 1758-9 that he made the acquaintance of another able and ardent student, imbued with predilections similar to his own, Mr. John Robison, afterwards, by Dr. Black's recommendation, appointed to succeed Dr. B. as Lecturer on Chemistry in the University of Glasgow; and who subsequently became eminent as Professor of Natural Philosophy in that of Edinburgh. Both of those learned persons, owing to the accidental circumstance of their testimony having been called for on occasion of infringements of Mr. Watt's patents, at a period nearly forty years subsequent to their first meeting at Glasgow, have left interesting narratives of the rise and progress of their intercourse with Mr. Watt, and of the origin of his first and greatest invention; which, as they do honour alike to their authors and their subject, we do not hesitate to place before our readers. That by Dr. Black, which is by much the shorter of the two, had never been noticed by any of the previous biographers of Watt, nor, indeed, did its existence appear to have been known to them; while from Dr. Robison's longer, but highly curious and important narrative, only a very brief extract was published by M. Arago.

History of Mr. Watt's Improvement of the Steam-Engine.

By JOSEPH BLACK, M.D.*

" I became acquainted with Mr. James Watt in the year " 1757 or 1758, at which time I was Professor of Medicine " and Lecturer of Chemistry in the University of Glasgow. " About that time Mr. Watt came to settle in Glasgow as a " maker of mathematical instruments; but being molested " by some of the corporations, who considered him as an " intruder on their privileges, the University protected him " by giving him a shop within their precincts, and by conferring on him the title of Mathematical Instrument Maker " to the University.

" I soon had occasion to employ him to make some things " which I needed for my experiments, and found him to be a " young man possessing most uncommon talents for mechanical " knowledge and practice, with an originality, readiness, and " copiousness of invention, which often surprised and delighted " me in our frequent conversations together. I also had " many opportunities to know that he was as remarkable for " the goodness of his heart, and the candour and simplicity " of his mind, as for the acuteness of his genius and understanding. I therefore contracted with him an intimate " friendship, which has continued and increased ever since " that time. I mention these circumstances only to show " how it happened that I was thoroughly acquainted with the " progress of his inventions, and with the different objects " that engaged his attention, while I remained at Glasgow, " and, in a great measure, ever since.

" A few years after he was settled at Glasgow he was " employed by the Professor of Natural Philosophy to examine " and rectify a small workable model of a steam-engine, which " was out of order. This turned a part of his thoughts and

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* The original document is in the hand-writing of Dr. Black. On the envelope in which it is enclosed, Dr. B. has written, " Mr. Watt's lawsuit, 1796-97."

" fertile invention to the nature and improvement of steam-" engines, to the perfection of their machinery, and to the " different means by which their great consumption of fuel " might be diminished. He soon acquired such a reputation " for his knowledge on this subject, that he was employed to " plan and erect several engines in different places, while at " the same time he was frequently making new experiments " to lessen the waste of heat from the external surface of the " boiler, and from that of the cylinder.

" But after he had been thus employed a considerable " time, he perceived that by far the greatest waste of heat " proceeded from the waste of steam in filling the cylinder " with steam. In filling the cylinder with steam, for every " stroke of the common engine a great part of the steam is " chilled and condensed by the coldness of the cylinder, before " this last is heated enough to qualify it for being filled with " elastic vapour or perfect steam; he perceived, therefore, " that by preventing this waste of steam, an incomparably " greater saving of heat and fuel would be attained than by " any other contrivance. It was thus, in the beginning of " the year 1765, that the fortunate thought occurred to him " of condensing the steam by cold in a separate vessel or " apparatus, between which and the cylinder a communi-" cation was to be opened for that purpose every time the " steam was to be condensed; while the cylinder itself might " be preserved perpetually hot, no cold water or air being " ever admitted into its cavity.

" This capital improvement flashed on his mind at once, " and filled him with rapture; and he immediately made a " hasty trial of it, which satisfied him of its value, employing " for this purpose a large brass syringe which he borrowed " from a friend."

Such is the first part of the concise, but emphatic and comprehensive account given by Dr. Black; the remainder of which we reserve till somewhat later in our narrative. In the meantime, we proceed to give the greater portion of that of Dr. Robison, which, entering more into detail, seems more entirely to place us, as it were, in the very presence, and reveal to us the whole course of thought and inquiry, of his inventive companion and friend. According to Mr. Watt's own statement, to Robison belongs the honour of having been the first who drew his attention to the subject of steam-engines;—in 1759 even suggesting their application to "the " moving of wheel-carriages," and to other purposes.

Narrative of Mr. Watt's Invention of the Improved Engine.

By PROFESSOR ROBISON.*

" My acquaintance with Mr. Watt began in 1758.† I " was then a student in the University of Glasgow, and " studying the science which I now profess to teach, Natural " Philosophy. The University was then building an astro- " nomical observatory. Mr. Watt came to settle in Glasgow " as a mathematical and philosophical instrument-maker, " and was employed to repair and set up a very noble collec- " tion of instruments bequeathed to the University by Mr. " Macfarlane of Jamaica, a gentleman well known to the " scientific world. Mr. Watt had apartments and a work- " shop within the College. I had, from my earliest youth, a " great relish for the natural sciences, and particularly for " mathematical and mechanical philosophy. I was eager to " be acquainted with the practice of astronomical observa- " tion, and my wishes were much encouraged by the cele- " brated Dr. Simson, Professor of Geometry, Dr. Dick, Pro- " fessor of Natural Philosophy, and Dr. Moor, Professor of " Greek;—gentlemen eminent for their mathematical abili- " ties. Those gentlemen brought me with them into Mr. " Watt's shop; and when he saw me thus patronised, or

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* The original is in the handwriting of Professor R., and is indorsed " Versus Hornblower and " Maberly, 1796."

† Mr. Watt, in his 'Recollections 'of his friend Dr. J. Robison,' written in April, 1805, says, "our acquaint- "ance began in 1756 or 57, when I '' was employed by the University of '' Glasgow to repair and put in order " some astronomical instruments, be- " queathed to the University by Mr. " Macfarlane of Jamaica." One of these earlier dates is no doubt the correct one, as Dr. Robison associates Dr. Dick's name with his first acquaintance with Mr. Watt, and Dr. Dick's death, as mentioned above, took place in 1757.

" introduced, his natural complaisance made him readily " indulge my curiosity."

Elsewhere,—in a letter to Mr. Watt, in 1799, on the death of Dr. Black,—Robison says, "My first acquaintance with " Dr. Black began in your rooms, when you were rubbing up " M'Farlane's instruments. Dr. Black used to come in, and, " standing with his back to us, amuse himself with Bird's " quadrant, whistling softly to himself, in a manner that " thrilled me to the heart. . . In the end of 1758, " when I went to sea, and had a favour to ask of the pro" fessors, Dr. Black spoke very handsomely of me. This " I learned at my return; but we had no further " acquaintance till then, or rather till 1764; and his " marked attention to me, (as he told me not long ago), was " owing to my saying distinctly, and giving reasons for it, " that Dr. Dick, my professor, had infinitely more know" ledge than his successor, who was much more popular. " Indeed, Dr. Black has often said to me, that Dick " was one of the most sensible and manly fellows he ever " knew."

" After first feasting my eyes with the view of fine instru" ments, and prying into everything, I conversed," continues Professor Robison, " with Mr. Watt. I saw a workman, and " expected no more; but was surprised to find a philosopher, " as young as myself, and always ready to instruct me. I " had the vanity to think myself a pretty good proficient in " my favourite study, and was rather mortified at finding " Mr. Watt so much my superior. But his own high relish " for those things made him pleased with the chat of any " person who had the same tastes with himself, or his innate " complaisance made him indulge my curiosity, and even " encourage my endeavours to form a more intimate " acquaintance with him. I lounged much about him, and, " I doubt not, was frequently teasing him. Thus our " acquaintance began.

" It was interrupted in 1759. I left the College for the " navy, where I was a midshipman four years, and was " present in some of the most remarkable actions of that

" war.* My health suffered so much by a seafaring life, that I " was obliged to give it up, much against my inclination, and " return to my academical habits. I was happy to find Mr. " Watt settled in Glasgow, as fond of science as ever. Our " acquaintance was renewed; I believe, with mutual satisfac- " tion, for I had now acquired some knowledge. I had lived " in the closest intimacy with the late Admiral Sir Charles " Knowles, and had been a good deal employed in marine " surveys. I had been employed by the Admiralty to make " the observations for the trial of Mr. Harrison's famous time- " piece; in short, my habits had been such, that I reckoned " myself more on a par with Mr. Watt, and hoped for a " closer acquaintance. Nor was I disappointed. I found " him as good and kind as ever, as keen after the acquisition " of knowledge, and well disposed to listen to the information " I could give him concerning things which had not fallen in " his own way. But I found him continually striking into " untrodden paths, where I was always obliged to be a fol- " lower.

" Our acquaintance at this time became very intimate, " and I believe neither of us engaged far in any train of " thought without the other sharing in it. I had had the " advantage of a more regular education: this frequently " enabled me to direct or confirm Mr. Watt's speculations, " and put into a systematic form the random suggestions of " his inquisitive and inventive mind. This kind of friendly " commerce knit us more together, and each of us knew the " whole extent of the other's reading and knowledge. I was " not singular in this attachment. All the young lads of our " little place that were any way remarkable for scientific pre- " dilection were acquaintances of Mr. Watt; and his parlour

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* Among the number, the storming of Quebec was perhaps the most conspicuous. On the eve of that victory, the triumph of which was so much embittered by the death of the gallant Wolfe, it happened that Mr. Robison was on duty in the boat in which that general went to visit some posts; and he has recorded that, as they rowed along, Wolfe repeated aloud nearly the whole of Gray's Elegy, and declared that "he would "prefer being the author of that "poem to the glory of beating the "French to-morrow." See 'Biographical Account of the late Professor 'Robison,' by Playfair.

" was a *rendezvous* for all of this description. Whenever any
" puzzle came in the way of any of us, we went to Mr.
" Watt. He needed only to be prompted; everything
" became to him the beginning of a new and serious study;
" and we knew that he would not quit it till he had either
" discovered its insignificance, or had made something of it.
" No matter in what line,—languages, antiquity, natural history,—
" nay, poetry, criticism, and works of taste; as to
" anything in the line of engineering, whether civil or military,
" he was at home, and a ready instructor. Hardly any
" projects, such as canals, deepening the river, surveys, or the
" like, were undertaken in the neighbourhood without consulting
" Mr. Watt; and he was even importuned to take the
" charge of some considerable works of this kind, though
" they were such as he had not the smallest experience in.
" When to this superiority of knowledge, which every man
" confessed in his own line, is added the *naïve* simplicity and
" candour of Mr. Watt's character, it is no wonder that the
" attachment of his acquaintances was strong. I have seen
" something of the world, and am obliged to say that I never
" saw such another instance of general and cordial attachment
" to a person whom all acknowledged to be their superior.
" But this superiority was concealed under the most
" amiable candour, and liberal allowance of merit to every
" man. Mr. Watt was the first to ascribe to the ingenuity of
" a friend things which were very often nothing but his own
" surmises, followed out and embodied by another. I am
" well entitled to say this, and have often experienced it in
" my own case.

" But the circumstance which made Mr. Watt's acquaintance
" so valuable to me, was the trait of character I have
" already mentioned. Everything became to him a subject
" of new and serious study,—everything became science in his
" hands; and I took every opportunity of offering my feeble
" aid, by prosecuting systematically, and with the help of
" mathematical discussion, thoughts which he was contented
" with having suggested or directed. I thus shared the
" fruits of his invention; and with gratitude I here acknow-

"ledge my obligations to him for that strong relish which I "thus acquired for rational mechanics, and which I have "cultivated with great assiduity and pleasure all my life. I "also shared with Mr. Watt a good deal of that subsidiary "knowledge, which he acquired as so many stepping-stones "in his way to some favourite objects. He learned the "German language in order to peruse Leupold's 'Theatrum "'Machinarum:'—so did I, to know what he was about. "Similar reasons made us both learn Italian; and so of "other things. And I cannot here pass over another circum- "stance which endeared Mr. Watt to us all: he was without "the smallest wish to appropriate knowledge to himself; "and one of his greatest delights was to set others on the "same road to knowledge with himself. No man could be "more distant from the jealous concealment of a tradesman; "and I am convinced that nothing but the magnitude of the "prospect which his improvement of the steam-engine held "out to him and his family, could have made Mr. Watt refuse "himself the pleasure of communicating immediately all his "discoveries to his acquaintances. Nay, he could *not* conceal "it; for, besides the frankly imparting it to Dr. Black, to "myself, and two or three more intimate friends, he disclosed "so much of what he had been doing, that had it been in "London or Birmingham, I am confident that two or three "patents would have been expedited, for bits of his method, "by bustling tradesmen, before he [would have] thought "himself entitled to solicit such a thing.

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"I doubt not but all this will be looked upon by some as "mere panegyric. The ignorant are insensible to the plea- "sures of science, and have no notion of the attachments "which this may produce; and the low-bred minds whose "whole thoughts are full of concealment, rivalship, and "money-making, can hardly conceive a mind that is not "actuated by similar propensities. But I have a better "opinion of those* on whose feelings and judgment the issue

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* The special jury, in the cause "Boulton and Watt *versus* Hornblower "and Maberly."

" of this cause is to depend. I wish to show these gentlemen " what were my opportunities of seeing the steps by which " Mr. Watt arrived at his final discovery; and I am not " afraid that they will misinterpret the satisfaction I feel in " having this opportunity of expressing my sentiments of " attachment to Mr. Watt. There is perhaps but one other " person now alive * who was a witness to every step of the " invention, and I regret exceedingly that his extreme illness " makes it impossible for my friend to avail himself of his " testimony. The thoughts of doing him an essential service " have supported me in my journey hither, under very considerable suffering; and when I find that not only the " fortune but the fair name of a most worthy man is concerned, I think that nothing less than life could have " excused me from the sound duty of every good citizen— " the support of eminent talents and worth against the vile " aspersions of low-bred and ignorant pretenders.

" I think it was in the summer of 1764, or perhaps in the " spring of that year,† that the Professor of Natural Philosophy in the University desired Mr. Watt to repair a pretty " model of Newcomen's steam-engine. This model was at " first a fine plaything to Mr. Watt and to myself, now a " constant visitor at the workshop; but, like everything " which came into his hands, it soon became an object of " most serious study. This model being an exact copy of a " real engine, the motion of the piston behoved to be the " same, and the strokes to be much more frequent. In consequence of this, the boiler was unable to supply more than " a few strokes. The boiler was made to boil more violently; " but this, instead of continuing the motion by a more plentiful supply of steam, stopped the machine altogether; and " we attributed this to the statical resistance to the entry of " the injection, which came from a height not much exceeding a foot. The injection-cistern was placed higher, " but without effect. It was long before the true cause was

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* Dr. Black.

† Mr. Watt has informed us that it was in the winter of 1763-4.

" thought of, and in the meantime many observations were " made on the performance.

" Mr. Watt had learned from Dr. Black somewhat of his " late discovery of the latent heat of fluids and of steams. " The Doctor had established his doctrine by means of incontrovertible experiments in the case of congelation and " liquefaction; but had not yet devised any very simple and " popular experiments for showing the much greater quantity " of heat which is contained in steam in a latent state. But " the great variety of curious and abstruse phenomena which " were explicable by this branch of the theory made it a " subject of much conversation among the young gentlemen " at college. Mr. Watt was one of the most zealous partisans " of this theory,* and this little job of the model came opportunely in his way, and immediately took his whole attention. He made many curious experiments; and Dr. Black " publicly acknowledges, in his lectures, his obligations to Mr. " Watt for the chief experiments by which he illustrates and " supports his theory. I had not yet studied chemistry, and " Mr. Watt was my first instructor. My mind was fired with " the inexhaustible fund of instruction and entertainment " which I now saw before me; and I was more assiduous in " my attendance on Mr. Watt's occupations than ever, and " studied the little model as much as he did. He very early " saw that an enormous quantity of steam was wasted. The " great heat acquired in an instant by the cylinder, by the " admission of a few grains of water in the form of steam, was " an incontestable proof of the great quantity of fire contained " in it; and as this could come only from the coals, Mr. Watt " saw at once that the chief improvements that the engine " was susceptible of must consist in contrivances for increasing " the production, and for diminishing its waste. He greatly " improved the boiler by increasing the surface to which the

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* *Note in the handwriting of Mr. Watt.*—" Dr. Robison is mistaken in " this. I had not attended to Dr. " Black's experiment or theory on " latent heat, until I was led to it in " the course of experiments upon the " engines, when the fact proved a " stumbling-block which the Doctor " assisted me to get over.—J. W."

" fire was applied; he made flues through the middle of the
" water; he placed the fire in the middle of the water; and
" made his boiler of wood, as a worse conductor of heat than
" the brickwork which surrounds common furnaces. He
" cased the cylinder, and all the conducting-pipes, in mate-
" rials which conducted heat very slowly; he even made them
" of wood. After much acquaintance with his models, (for
" he had now made others), he found that there was still a
" prodigious and unavoidable waste of steam and fuel, arising
" from the necessity of cooling the cylinder very low at every
" effective stroke; and he was able to show that more than
" three-fourths of the whole steam was thus condensed and
" wasted during the ascent of the piston. (Subsequent expe-
" riments, made with better apparatus, showed him that the
" waste was much greater than this.) I had seen all these
" contrivances, and many of the experiments, and had some-
" times contributed my mite to lessen the expensive waste;
" but this great cause of loss seemed to be unavoidable.

"At the breaking-up of the College, (I think in 1765), I
" went to the country. About a fortnight after this, I came
" to town, and went to have a chat with Mr. Watt, and to
" communicate to him some observations I had made on
" Desaguliers' and Belidor's account of the steam-engine.
" I came into Mr. Watt's parlour without ceremony, and
" found him sitting before the fire, having lying on his knee
" a little tin cistern, which he was looking at. I entered
" into conversation on what we had been speaking of at last
" meeting,—something about steam. All the while, Mr. Watt
" kept looking at the fire, and laid down the cistern at the
" foot of his chair. At last he looked at me, and said briskly,
" 'You need not *fash* yourself any more about that, man; I
" 'have now made an engine that shall not waste a particle
" 'of steam. It shall all be boiling hot;—aye, and hot water
" 'injected if I please.' So saying, Mr. Watt looked with
" complacency at the little thing at his feet, and, seeing that
" I observed him, he shoved it away under a table with his
" foot. I put a question to him about the nature of his con-
" trivance. He answered me rather drily. I did not press

" him to a further explanation at that time, knowing that I
" had offended him a few days before by blabbing a pretty
" contrivance which he had hit on for turning the cocks of
" the engine. I had mentioned this in presence of an engine-
" builder, who was going to erect one for a friend of mine; and
" this having come to Mr. Watt's ears, he found fault with it.

" I was very anxious, however, to learn what Mr. Watt
" had contrived, but was obliged to go to the country in
" the evening. A gentleman who was going to the same
" house said that he would give me a place in his car-
" riage, and desired me to wait for him on the walk by
" the river-side. I went thither, and found Mr. Alexander
" Brown, a very intimate acquaintance of Mr. Watt's, walk-
" ing with another gentleman, (Mr. Craig, architect). Mr.
" Brown immediately accosted me with, 'Well, have you seen
" 'Jamie Watt?'—'Yes.'—'He 'll be in high spirits now
" 'with his engine, isn't he?' 'Yes,' said I, 'very fine
" 'spirits.' 'Gad,' says Mr. Brown, 'the condenser 's the
" 'thing: keep it but cold enough, and you may have a
" 'perfect vacuum, whatever be the heat of the cylinder.'
" The instant he said this, the whole flashed on my mind at
" once. I did all I could to encourage the conversation, but
" was much embarrassed. I durst not appear ignorant of the
" apparatus, lest Mr. Brown should find that he had commu-
" nicated more than he ought to have done. I could only
" learn that there was a vessel called a condenser, which com-
" municated with the cylinder, and that this condenser was
" immersed in cold water, and had a pump to clear it of the
" water which was formed in it. I also learned that the great
" difficulty was to make the piston tight; and that leather
" and felt had been tried, and were found quite unable to
" stand the heat. I saw that the whole would be perfectly
" dry, and that Mr. Watt had used steam instead of air to
" press up his piston, which I thought, by Mr. Brown's de-
" scription, was inverted. We parted, and I went home, a
" very silent companion to the gentleman who had given me
" a seat. Next day, impatient to see the effects of the sepa-
" rate condensation, I sent to Paisley and got some tin things

" made there, in completion of the notion that I had formed. " I tried it as an air-pump, by making my steam-vessel com- " municate with a tea-kettle, a condenser, and a glass receiver. " In less than two minutes I rarefied the air in a pretty large " receiver more than twenty times. I could go no farther in " this process, because my pump for taking out the air from " my condenser was too large, and not tight enough; but I " saw that when applied to the mere purpose of taking out " the air generated from the water, the vacuum might be " made almost complete. I saw, too, (in consequence of a " conversation the preceding day with Mr. Watt about the " eduction-pipe in Beighton's engine), that a long suck-pipe, " or syphon, would take off all the water. In short, I had no " doubt that Mr. Watt had really made a perfect steam-engine.

* * * * *

" I think it was the middle of winter before I saw Mr. Watt. " When we met, he most frankly told me all his contrivance; " and I took care to receive it all as perfectly new to me, " that I might not commit Mr. Brown. I remember well, " that when he complained of the great power expended in " working pumps sufficiently large to exhaust a condenser " even of moderate size, (because they must do it at one " stroke against the whole pressure of the atmosphere), I " mentioned the observation that I had formerly made to " him on the eduction-pipe of Beighton's engine, and the " contrivance which I would deduce from it for clearing the " condenser of water. Mr. Watt said, ' O man, do you ima- " ' gine me so dull as not to have thought on that long ago? " ' But I could give you many reasons why it will not answer " ' so well as a pump. I wish I could as quickly get quit of " ' the air as of the water, without a pump. I don't despair " ' even of this.' He now informed me of many curious pro- " perties of steam relative to its heat and elasticity, explained " his methods of condensation, and mentioned some remark- " able facts relative to this subject, which pass to this day " before the eyes of everybody, without being noticed or " understood by hundreds who call themselves engineers and " builders of steam-engines.

"After this time my meetings with Mr. Watt were less
"frequent. He was much from home, working with his
"engine; and I was now obliged to devote my whole attention
"to another subject. Dr. Black, my preceptor in chemistry,
"was now removed to Edinburgh; and, by his very
"unmerited recommendation, the University of Glasgow
"placed me in the chemical chair which he had just quitted.
"Frightened by my own good fortune, I was obliged to strain
"every nerve to do some credit to so partial a recommendation;
"and I was obliged to relinquish all other occupations
"of my thoughts. But I had now learned all the principles
"of Mr. Watt's invention, though I had never seen either his
"engine or any model or drawing of it. I knew of his employing
"steam in place of the atmosphere to press forward
"his piston, although it was long ere I knew the way in
"which he introduced it. I thought he simply admitted it
"from the surrounding case by the open mouth of the cylinder;
"and it was not till I was in St. Petersburgh that I
"learned that he also introduced it, (without a steam-case),
"by a pipe. This, however, was a *natural* part of the leading
"thought; and, indeed, was practised by him in his very first
"experiment.

"In this experiment, (which was made with a common
"anatomist's great injection-syringe for a cylinder), the
"piston-rod passed through a collar of leathers in the cover
"of the cylinder, and the steam was admitted through another
"aperture in the same cover; and it escaped into the
"condenser by a similar aperture in a cover on the other end
"of the cylinder. Long after this, I found that the little
"apparatus which I saw on his knee, and which he shoved
"under the table with his foot, was the condenser in this first
"experiment. I discovered that I had not comprehended the
"whole contrivance so completely as I imagined. But though
"I was ashamed of my ignorance, my vanity would not let
"me acknowledge it; and I took circuitous ways of learning
"more exactly the precise state of the engine. I was living
"in Edinburgh during the summer of 1767, near Dr. Black,
"in order to prepare myself for my arduous task; and in my

" conversations with Dr. Black I frequently introduced Watt's " steam-engine. I one day asked him why Mr. Watt never " thought of impelling the piston by steam much stronger " than common steam, mentioning the way in which I would " introduce and manage it. He then corrected me in some " parts of my proposed construction, and described Mr. Watt's " with accuracy; and bade me reflect on the enormous size " and strength which must be given to the boiler, and the expense of fuel in supplying steam so dense and so hot. All " this I had thought on already, and only wanted to learn " what he had just now told me; and now I am fully entitled " to say, that in the summer of 1767 the whole contrivance " was perfect in Mr. Watt's mind, although he had neither " executed the double stroke, nor that most beautiful contrivance of cutting off the steam before the piston reaches " the bottom of the cylinder; a contrivance which in a " moment fits the engine, however great and powerful, to any " the most trifling task, and makes it more manageable than " any other engine whatever that is not immediately actuated " by the hand of man. Indeed, any person who deserves the " name of engineer must see, and, if he speak from the conviction of his conscience, must acknowledge, that the whole " contrivance was perfect in Mr. Watt's mind in his very first " trial.

" During the. two following winters, notwithstanding Mr. " Watt's frequent absence from Glasgow, and my constant " occupation with my chemical lectures, I had many opportunities of conversing with him, and learned all his difficulties and embarrassments. He struggled long to condense " with sufficient rapidity without injection, and exhibited " many beautiful specimens of ingenuity and fertility of resource. Many pretty schemes occurred to him for a rotatory engine. Some of these I am sorry to find that he has " neglected. I am confident of their complete success; and " though I agree with him in thinking that his engine with a " double stroke is superior to them all, I should have been " glad that they had been executed, because they would have " given a most brilliant specimen of his wonderful ingenuity

"and of his knowledge; for, indeed, the management of
"steam to perfection is the employment of an accomplished
"philosopher.

* * * * *

"During my residence in Glasgow I was in habits of con-
"tinual intimacy with Mr. Watt. All who knew him know
"that it is his greatest pleasure to communicate his know-
"ledge to those who have a relish for it. I have reason to
"think that he never, from any kind of jealousy, concealed
"anything from me. From the day that he—I may almost
"say *we*—began to play with the College model, I knew
"almost every step of his thoughts. He was confined to his
"business; I was more at large, and going about the College.
"I ransacked the libraries for every book that he wanted;
"and every quotation that he met with made him impatient
"till he got at the original. I saw every book that he got by
"any other channel besides the public libraries. So I may
"safely say that I knew the whole extent of his reading.
"Our abode was too far out of the circle of business for allow-
"ing us to be informed of the numberless projects that are
"every day born and buried in this busy country. I can say,
"with great confidence, that nothing ever occurred to Mr.
"Watt, either by reading or information, of his leading prin-
"ciple, of a steam-vessel perpetually and universally hot.
"All the other contrivances, of separate condenser,—air and
"water-pumps,—amalgam, or rosins, or fats for keeping the
"piston air-tight,—are but so many emanations from this
"first thought; and I will venture to say they all came into
"his mind in succession, and nearly in the order I have stated,
"after he said to himself, 'Let me make an engine, working
"'by a piston, in which the cylinder shall be continually hot
"'and perfectly dry.' I will venture to say that in no book
"previous to that date is there any account or proposal of
"such a thing, if we except some attempts to put the steam-
"vessel of Worcester's or Savery's engine in this predicament,
"by means of a travelling mass of oil or air, which was to be
"interposed between the steam and the water that was to be
"raised. Of these, Mr. Watt and I had some very imperfect

" account; but they never interested him, because the very " nature of the operation made it impossible to do anything " more than approximate to the desired object.

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"I must say, further, that the thought was wholly Mr. " Watt's. For this I have every authority that can be wished " for. I am certain that when I went out of town in (May, I " think,) 1765, he had not thought of the method of keeping " the cylinder hot; and I am as certain that a fortnight after " he had completed it, and confirmed it by experiment. Dr. " Black, the first philosophical chemist of his time, and the " most scrupulous man upon earth with respect to claims of " originality, gave this to Mr. Watt in the most unqualified " terms, the first time I saw him after I had learned it from " Mr. Brown, and long before I saw Mr. Watt and got it more " distinctly from himself." * * *

CHAPTER VII.

MR. WATT'S NARRATIVE OF THE INVENTIONS DESCRIBED IN HIS SPECIFICATION OF 1769, GIVEN IN HIS NOTES ON ROBISON — FURTHER ANECDOTES OF HIS INVENTION OF THE SEPARATE CONDENSER — HIS NARRATIVE ENTITLED "A PLAIN STORY."

THE account given by Mr. Watt himself, in his Notes on Professor Robison's Dissertation on Steam-engines,* is as follows:—

"My attention was first directed, in the year 1759, to the "subject of steam-engines, by the late Dr. Robison, then a "student in the University of Glasgow, and nearly of my own "age. He at that time threw out an idea of applying the "power of the steam-engine to the moving of wheel-carriages, "and to other purposes; but the scheme was not matured, "and was soon abandoned on his going abroad.

"About the year 1761, or 1762, I tried some experiments "on the force of steam in a Papin's digester, and formed a "species of steam-engine by fixing upon it a syringe, one-third "of an inch diameter, with a solid piston, and furnished also "with a cock to admit the steam from the digester, or shut "it off at pleasure, as well as to open a communication from "the inside of the syringe to the open air, by which the steam "contained in the syringe might escape. When the communication between the digester and syringe was opened, the "steam entered the syringe, and by its action upon the piston "raised a considerable weight (15 lbs.) with which it was "loaded. When this was raised as high as was thought "proper, the communication with the digester was shut, and "that with the atmosphere opened; the steam then made its "escape, and the weight descended. The operations were "repeated, and, though in this experiment the cock was

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* Robison's Mechanical Works, edited by Sir David Brewster.

" turned by hand, it was easy to see how it could be done by " the machine itself, and to make it work with perfect regu- " larity. But I soon relinquished the idea of constructing an " engine upon its principle, from being sensible it would be " liable to some of the objections against Savery's engine, " viz., the danger of bursting the boiler, and the difficulty of " making the joints tight, and also that a great part of the " power of the steam would be lost, because no vacuum was " formed to assist the descent of the piston. I, however, " described this engine in the fourth article of the specifica- " tion of my patent of 1769; and again in the specification " of another patent in the year 1784, together with a mode " of applying it to the moving of wheel-carriages.

" The attention necessary to the avocations of business pre- " vented me from then prosecuting the subject further; but " in the winter of 1763–4, having occasion to repair a model " of Newcomen's engine belonging to the Natural Philosophy " class of the University of Glasgow, my mind was again " directed to it. At that period my knowledge was derived " principally from Desaguliers, and partly from Belidor. I " set about repairing it as a mere mechanician; and when " that was done, and it was set to work, I was surprised to " find that its boiler could not supply it with steam, though " apparently quite large enough, (the cylinder of the model " being two inches in diameter, and six inches stroke, and " the boiler about nine inches diameter). By blowing the " fire it was made to take a few strokes, but required an " enormous quantity of injection water, though it was very " lightly loaded by the column of water in the pump. It " soon occurred that this was caused by the little cylinder " exposing a greater surface to condense the steam, than " the cylinders of larger engines did in proportion to their " respective contents. It was found that by shortening the " column of water in the pump, the boiler could supply the " cylinder with steam, and that the engine would work regu- " larly with a moderate quantity of injection. It now " appeared that the cylinder of the model, being of brass, " would conduct heat much better than the cast-iron cylinders

“ of larger engines, (generally covered on the inside with a
“ stony crust), and that considerable advantage could be
“ gained by making the cylinders of some substance that
“ would receive and give out heat slowly. Of these, wood
“ seemed to be the most likely, provided it should prove
“ sufficiently durable. A small engine was, therefore, constructed,
“ with a cylinder six inches diameter, and twelve
“ inches stroke, made of wood, soaked in linseed oil, and
“ baked to dryness. With this engine many experiments
“ were made; but it was soon found that the wooden cylinder
“ was not likely to prove durable, and that the steam condensed
“ in filling it still exceeded the proportion of that
“ required for large engines, according to the statements of
“ Desaguliers. It was also found that all attempts to produce
“ a better exhaustion by throwing in more injection, caused a
“ disproportionate waste of steam. On reflection, the cause
“ of this seemed to be the boiling of water in vacuo at low
“ heats, a discovery lately made by Dr. Cullen and some
“ other philosophers, (below 100°, as I was then informed);
“ and consequently, at greater heats, the water in the cylinder
“ would produce a steam which would, in part, resist the
“ pressure of the atmosphere.

“ By experiments which I then tried upon the heats at
“ which water boils under several pressures greater than that
“ of the atmosphere, it appeared that when the heats proceeded
“ in an arithmetical, the elasticities proceeded in some
“ geometrical ratio; and, by laying down a curve from my
“ data, I ascertained the particular one near enough for my
“ purpose. It also appeared, that any approach to a vacuum
“ could only be obtained by throwing in large quantities of
“ injection, which would cool the cylinder so much as to
“ require quantities of steam to heat it again, out of proportion
“ to the power gained by the more perfect vacuum; and
“ that the old engineers had acted wisely in contenting themselves
“ with loading the engine with only six or seven pounds
“ on each square inch of the area of the piston. It being
“ evident that there was a great error in Dr. Desaguliers’
“ calculations of Mr. Beighton’s experiments on the bulk of

" steam, a Florence flask, capable of containing about a pound " of water, had about one ounce of distilled water put into " it; a glass tube was fitted into its mouth, and the joining " made tight by lapping that part of the tube with pack- " thread, covered with glazier's putty. When the flask was " set upright, the tube reached down near to the surface of " the water, and in that position the whole was placed in a " tin reflecting oven before a fire, until the water was wholly " evaporated, which happened in about an hour, and might " have been done sooner had I not wished the heat not much " to exceed that of boiling water. As the air in the flask " was heavier than the steam, the latter ascended to the top, " and expelled the air through the tube. When the water " was all evaporated, the oven and flask were removed from " the fire, and a blast of cold air was directed against one " side of the flask, to collect the condensed steam in one " place. When all was cold, the tube was removed; the flask " and its contents were weighed with care; and the flask " being made hot, it was dried by blowing into it by bellows, " and when weighed again, was found to have lost rather " more than four grains, estimated at 4⅓ grains. When the " flask was filled with water, it was found to contain about " 17⅛ ounces avoirdupois of that fluid, which gave about 1800 " for the expansion of water converted into steam of the heat " of boiling water.

" This experiment was repeated with nearly the same " result; and in order to ascertain whether the flask had " been wholly filled with steam, a similar quantity of water " was for the third time evaporated; and, while the flask was " still cold, it was placed inverted, with its mouth (contracted " by the tube) immersed in a vessel of water, which it sucked " in as it cooled, until in the temperature of the atmosphere " it was filled to within half an ounce measure of water. In " the contrivance of this experiment I was assisted by Dr. " Black. In Dr. Robison's edition of Dr. Black's Lectures, " vol. i., p. 147, the latter hints at some experiments upon " this subject, as made by *him;* but I have no knowledge of " any except those which I made myself.

"In repetitions of this experiment at a later date, I sim-
" plified the apparatus by omitting the tube and laying the
" flask upon its side in the oven, partly closing its mouth by
" a cork, having a notch on one side, and otherwise pro-
" ceeding as has been mentioned.

"I do not consider these experiments as extremely accu-
" rate, the only scale-beam of a proper size which I had then
" at my command not being very sensible, and the bulk of
" the steam being liable to be influenced by the heat to which
" it is exposed, which, in the way described, is not easily
" regulated or ascertained; but, from my experience in actual
" practice, I esteem the expansion to be rather more than I
" have computed.

"A boiler was constructed which showed, by inspection,
" the quantity of water evaporated in any given time, and
" thereby ascertained the quantity of steam used in every
" stroke by the engine, which I found to be several times the
" full of the cylinder. Astonished at the quantity of water
" required for the injection, and the great heat it had acquired
" from the small quantity of water in the form of steam which
" had been used in filling the cylinder, and thinking I had
" made some mistake, the following experiment was tried:—
" A glass tube was bent at right angles; one end was inserted
" horizontally into the spout of a tea-kettle, and the other
" part was immersed perpendicularly in well-water contained
" in a cylindric glass vessel, and steam was made to pass
" through it until it ceased to be condensed, and the water in
" the glass vessel was become nearly boiling hot. The water
" in the glass vessel was then found to have gained an addi-
" tion of about one-sixth part from the condensed steam.
" Consequently, water converted into steam can heat about
" six times its own weight of well-water to 212°, or till it can
" condense no more steam. Being struck with this remark-
" able fact, and not understanding the reason of it, I men-
" tioned it to my friend Dr. Black, who then explained to me
" his doctrine of latent heat, which he had taught for some
" time before this period (summer 1764); but having myself
" been occupied with the pursuits of business, if I had heard

" of it, I had not attended to it, when I thus stumbled upon " one of the material facts by which that beautiful theory is " supported.

" On reflecting further, I perceived, that in order to make " the best use of steam, it was necessary—first, that the " cylinder should be maintained always as hot as the steam " which entered it; and, secondly, that when the steam was " condensed, the water of which it was composed, and the " injection itself, should be cooled down to 100°, or lower, " where that was possible. The means of accomplishing these " points did not immediately present themselves; but early " in 1765 it occurred to me, that if a communication were " opened between a cylinder containing steam, and another " vessel which was exhausted of air and other fluids, the " steam, as an elastic fluid, would immediately rush into the " empty vessel, and continue so to do until it had established " an equilibrium; and if that vessel were kept very cool by " an injection, or otherwise, more steam would continue to " enter until the whole was condensed. But both the vessels " being exhausted, or nearly so, how were the injection-water, " the air which would enter with it, and the condensed steam, " to be got out? This I proposed, in my own mind, to perform in two ways. One was, by adapting to the second " vessel a pipe, reaching downwards more than 34 feet, by " which the water would descend, (a column of that length " overbalancing the atmosphere), and by extracting the air " by means of a pump.

" The second method was by employing a pump, or pumps, " to extract both the air and the water, which would be " applicable in all places, and essential in those cases where " there was no well or pit.

" This latter method was the one I then preferred, and is " the only one I afterwards continued to use.

" In Newcomen's engine, the piston is kept tight by water, " which could not be applicable in this new method; as, if " any of it entered into a partially-exhausted and hot cylin- " der, it would boil, and prevent the production of a vacuum, " and would also cool the cylinder by its evaporation during "the descent of the piston. I proposed to remedy this defect "by employing wax, tallow, or other grease, to lubricate and "keep the piston tight. It next occurred to me, that the "mouth of the cylinder being open, the air which entered to "act on the piston would cool the cylinder, and condense "some steam on again filling it. I therefore proposed to put "an air-tight cover upon the cylinder, with a hole and stuffing-"box for the piston-rod to slide through, and to admit steam "above the piston to act upon it, instead of the atmosphere. "The piston-rod sliding through a stuffing-box was new in "steam-engines; it was not necessary in Newcomen's engine, "as the mouth of the cylinder was open, and the piston-rod "was square and very clumsy. The fitting the piston-rod "to the piston by a cone was an after-improvement of mine, "(about 1774). There still remained another source of the "destruction of steam, the cooling of the cylinder by the "external air, which would produce an internal condensation "whenever steam entered it, and which would be repeated "every stroke; this I proposed to remedy by an external "cylinder, containing steam, surrounded by another of wood, "or of some other substance which would conduct heat "slowly.

"When once the idea of the separate condensation was "started, all these improvements followed as corollaries in "quick succession, so that in the course of one or two days "the invention was thus far complete in my mind, and I "immediately set about an experiment to verify it practically. "I took a large brass syringe, 1¾ inches diameter and 10 "inches long, made a cover and bottom to it of tin-plate, "with a pipe to convey steam to both ends of the cylinder "from the boiler; another pipe to convey steam from the "upper end to the condenser (for, to save apparatus, I in-"verted the cylinder); I drilled a hole longitudinally through "the axis of the stem of the piston, and fixed a valve at its "lower end, to permit the water, which was produced by the "condensed steam on first filling the cylinder, to issue. The "condenser used upon this occasion consisted of two pipes of "thin tin-plate, ten or twelve inches long, and about one-sixth

" inch diameter, standing perpendicular, and communicating " at top with a short horizontal pipe of large diameter, having " an aperture on its upper side, which was shut by a valve " opening upwards. These pipes were joined at bottom to " another perpendicular pipe of about an inch diameter, " which served for the air and water-pump; and both the " condensing pipes and the air-pump were placed in a small " cistern filled with cold water. This construction of the condenser was employed from knowing that heat penetrated " thin plates of metal very quickly, and considering that if " no injection was thrown into an exhausted vessel, there " would be only the water of which the steam had been composed, and the air which entered with the steam, or through " the leaks, to extract.

" The steam-pipe was adjusted to a small boiler. When " steam was produced, it was admitted into the cylinder, and " soon issued through the perforation of the rod, and at the " valve of the condenser. When it was judged that the air " was expelled, the steam-cock was shut, and the air-pump " piston-rod was drawn up, which leaving the small pipes of " the condenser in a state of vacuum, the steam entered them " and was condensed. The piston of the cylinder immediately " rose, and lifted a weight of about 18 lbs., which was hung " to the lower end of the piston-rod. The exhaustion-cock " was shut, the steam was readmitted into the cylinder, and " the operation was repeated; the quantity of steam consumed, and the weights it could raise, were observed; and, " excepting the non-application of the steam-case and external " covering, the invention was complete, in so far as regarded " the savings of steam and fuel. A large model, with an " outer cylinder and wooden case, was immediately constructed, and the experiments made with it served to verify " the expectations I had formed, and to place the advantage " of the invention beyond the reach of doubt. It was found " convenient afterwards to change the pipe-condenser for an " empty vessel, generally of a cylindrical form, into which an " injection played, and, in consequence of there being more " water and air to extract, to enlarge the air-pump.

"The change was made because, in order to procure a "surface sufficiently extensive to condense the steam of a "large engine, the pipe-condenser would require to be very "voluminous, and because the bad water with which engines "are frequently supplied would crust over the thin plates, "and prevent their conveying the heat sufficiently quick. "The cylinders were also placed with their mouths upwards, "and furnished with a working-beam, and other apparatus, "as was usual in the ancient engines;—the inversion of the "cylinder, or rather of the piston-rod, in the model, being "only an expedient to try more easily the new invention, "and being subject to many objections in large engines.

"In 1768 I applied for letters patent for my 'Methods of "'Lessening the Consumption of Steam, and, consequently, "'of Fuel, in Fire-Engines,' which passed the seals in "January, 1769; and my Specification was enrolled in "Chancery in April following."

Mr. John Hart, an ingenious tradesman of Glasgow, who was a native of Borrowstoness, and, together with his brother Robert, already mentioned, was distinguished by a predilection for the practical arts connected with science, has related that Mr. Watt frequently conversed with him on subjects of mechanical interest; and that being asked by him, in 1817, whether he recollected how the first idea of his great discovery came into his mind, he replied, "O yes, perfectly. "One Sunday afternoon I had gone to take a walk in the "Green of Glasgow,* and when about half way between the "Herd's House and Arn's Well, my thoughts having been "naturally turned to the experiments I had been engaged in "for saving heat in the cylinder, *at that part of the road* the "idea occurred to me, that, as steam was an elastic vapour, it "would expand, and rush into a previously exhausted space; "and that, if I were to produce a vacuum in a separate vessel, "and open a communication between the steam in the

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* "The large open meadow which "lies on the northern bank of the "Clyde, and serves at once as a "bleaching-field and pleasure-walk "for the inhabitants."—Sir W. Scott, ROB ROY, chap. xxi. Abbotsford edition, vol. iii. p. 165.

"cylinder and the exhausted vessel, such would be the consequence." *

Without dwelling on the particular scenes of these minute recollections, which, however, may in future interest the local topographer and antiquary, we do not fear being accused of undue repetition if we lay before the reader a more careful history, also given by Mr. Watt, of the origin and early progress of his inventions, in so far as they were specified in relation to his first patent. This interesting document was prepared by him in 1796, as a general answer to the objections which his opponents, in the litigation already referred to, raised to the specification. Expressed in language both precise and clear, it was originally intended for the information of counsel, and, through them, of the Court; and was by its unassuming author, with characteristic simplicity, entitled—

A PLAIN STORY.

"W. found that a well-made brass model of Newcomen's engine consumed quantities of steam and fuel out of all reasonable or direct proportion with larger engines. He consulted Desaguliers' 'Natural Philosophy,' and Belidor's 'Architecture Hydraulique,' the only books from which he could hope for information. He found that both of them reasoned learnedly, but by no means satisfactorily; and that Desaguliers had committed a very gross arithmetical error in calculating the bulk of steam from the water evaporated in a common steam-engine; which being rectified, it appeared next that his data, or assumed facts, were false. By a simple experiment, W. found what was the real bulk of water converted into steam; and from his friend Dr. Black he learned what was the heat absorbed and rendered latent by the conversion of water into steam, which

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* From a MS. notice communicated by the late Dr. John Smith, of Glasgow, long the respected Secretary to the Maitland Club; to which literary society he, in 1832, presented the "Burgh Records of the City of "Glasgow, M.D.LXXII—M.D.LXXXI."

" the Doctor then publicly taught, and had done for some
" years. Experiments had been made long before by Dr.
" Cullen, Mr. John Robison, and others, in public classes,
" which proved that water, when placed in an exhausted
" receiver, boiled, and was converted into steam at the heat
" of 70° or 80° of Fahrenheit's thermometer, while it was
" well known that under the pressure of the atmosphere it
" required 212° of heat to make it boil, and emit steam
" capable of displacing the air. It was evident, that, under
" intermediate pressures, intermediate degrees of heat would
" be required to make it boil, and that in the steam-engine
" more or less cold water must be thrown in according to the
" degree of exhaustion which might be required; or, in other
" words, according to the number of pounds per inch the
" engine was loaded to.

" Newcomen's and Savery's engines existed; the latter
" were in general laid aside, on several accounts, but the
" principal one seems to have been that the cold water, the
" raising of which formed the effect of the engine, entered
" the steam-vessel itself, which in general was not a cylinder,
" but was of an oval or egg form; and, by cooling it,
" destroyed a great quantity of steam when it came next to
" be filled, which Desaguliers expressly notices. This engine,
" however, had an injection of cold water, to commence the
" condensation of steam, and Savery seems to have been the
" inventor of that valuable article;* but he also seems in
" some cases to have condensed the steam by pouring cold
" water on the outside of his copper steam-vessel.

" In Newcomen's engine the steam-vessel was a cylinder,
" or so meant to be. A piston was suspended, moveable in
" that cylinder; this piston hung by chains to the arch of a
" strong double-ended lever like a scale-beam, to the other
" end of which the rods which wrought the pumps were suspended in the like manner. The steam was admitted from
" a covered boiler, through a pipe, into the cylinder below
" the piston; the air was blown out by the steam at a pipe

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* Ascribed, however, by Desaguliers, vol. ii. p. 533, to Newcomen and Cawley.

"near the bottom of the cylinder, called the *snift*. The "passage from the boiler was shut; cold water was spouted "or injected into the cylinder from a cistern placed higher; "the steam was thus condensed or rendered less elastic, the "other end or mouth of the cylinder being open; the "pressure of the atmosphere, not being resisted by an equally "elastic fluid within, or under the piston, weighed upon the "latter and caused it to descend, which, by means of the "lever, drew up the pump-rods and raised the water. The "injection-cock or valve was then shut, the steam-regulator "or valve was opened, steam was readmitted, the equilibrium "of pressure upon the upper and under sides of the piston "was restored, and the superior weight of the pump-rods, by "means of the great lever or working beam, drew the piston "to the top of the cylinder, and the operation recommenced. "When the piston was at the bottom of the cylinder, the air "which entered with the steam and with the injection water "was blown out at the snift, and the hot water left in the "cylinder was expelled through another pipe, called the "*eduction-pipe*, which proceeded from the bottom of the "cylinder, several feet downwards, and its lower end stood in "a cistern of water, and was furnished with a valve to prevent regress.

"The steam-valve and the injection-cock were opened and "shut by certain mechanism called working gear, which was "put in motion by means of pegs in a piece of wood which "was hung to and moved with the working beam, and was "called the plug-tree.

[illegible] Hu Potte lad a boy [illegible]

"In order to supply the engine with cold water, it wrought "a pump called a jack-head pump, which was shut at top by "an iron cover, and its pump-rod wrought through a collar "of oakum, which permitted the rod to slide up and down, "while it precluded the exit of the water, which was raised "to a greater height through a side branch turned upwards.

"Thus the latent heat of steam was discovered and pub-"lished by Dr. Black; the boiling of water *in vacuo*, at low "degrees of heat, was discovered and published by Dr. Cul-"len, Mr. Robison, and several others.

" The elastic powers of steam were known to Hero of " Alexandria, and to many ancient writers. The steam- " engine was invented by the Marquis of Worcester, Savery, " Papin, and Newcomen.

" The means of confining steam, and the making valves, " cocks, and regulators, were known to all of them. Pumps " for drawing both air and water out of vessels or reservoirs " were well known to everybody. An air-pump, with a " piston-rod *moving through a collar*, was invented and pub- " lished by Mr. Smeaton; and the same method, even before " him, was commonly used in the jack-head pumps of common " steam-engines, and in other machines; (this relates to the " piston-rod of the cylinder; for, in respect to the air-pump, " it is not necessary, though convenient, that it be shut at " top).

" A cylinder and moveable piston were used in New- " comen's engine; so were the working beam and working " gear, or machinery for opening and shutting the valves and " cocks.

" The steam was condensed by a spout of cold water in " Savery's and in Newcomen's engines; and, as it is said in " Desaguliers, cold water was poured on the outside of the " steam-vessels for the same purpose. Everybody knew that " cold bodies of all kinds condensed steam when they came " in contact with it. There were pipes in all those engines " which admitted the steam from the boiler, and cocks or " valves which shut it out from that vessel; and in New- " comen's engine there was a pipe which conveyed away the " hot water, and a valve which prevented its regress.

" The diameters of those pipes, which admitted the steam " and let out the injection-water, had been ascertained suffi- " ciently near. The size and form of boilers, which answered " sufficiently well, had also been ascertained.

" Of all those things, Watt must say, '*Non ea nostra voco.*' " The things that are his remain to be told.

" He found, by the application of the knowledge which has " been mentioned, that the cause of the great consumption of " fuel was, that the cylinder being cooled by the injection-

" water, that vessel *must* condense a large quantity of steam " whenever it was attempted to be again filled with steam; " that the vacuum could not approach to perfection without " the steam was cooled below 100°; and that such cooling " would increase the evil complained of in a fourfold or " greater ratio, because the penetration of the heat or cold " into the cylinder would be as the squares of the differences " of the heats between that vessel and the steam. How was " this to be avoided?

" He tried to make the cylinders of wood or other materials " which conduct heat slowly, but he could not prevent the " steam from coming into contact with the comparatively " cold water which remained in the bottom of the cylinder, " and which must be expelled by the steam; besides, his " wooden cylinders did not seem likely to be of long duration. " In such-like experiments he spent much time, and more " money than was suitable to his circumstances, yet he made " no advances towards a beneficial discovery. But the matter " having got firm hold of his mind, and his circumstances " obliging him to make exertions to regain what he had spent, " he turned the matter over in every shape, and laid it down " as an axiom,—*that to make a perfect steam-engine, it was* " *necessary that the cylinder should be always as hot as the* " *steam which entered it, and that the steam should be cooled* " *down below* 100° *in order to exert its full powers.* The gain " by such construction would be double:—first, no steam " would be condensed on entering the cylinder; and secondly, " the power exerted would be greater as the steam was more " cooled. The *postulata*, however, seemed to him incom- " patible, and he continued to grope in the dark, misled by " many an *ignis fatuus*, till he considered that steam being " an elastic fluid, it must follow the law of its kind; and " that if there were two vessels, A and B, of equal or other " dimensions, the one, A, filled with steam, and the other, B, " exhausted, if a communication were opened between those " vessels, the steam would rush from the full one into the " empty one, and they would both remain half exhausted, (if " the vessels were equal in size), or be filled with steam of

" half the density. If, then, into the second vessel, B, an
" injection of cold water were made, or cold water applied to
" its outside in sufficient quantity, the portion of steam which
" it contained would be condensed or reduced to water; and
" by the same law of nature that had operated before, more
" steam would issue from A into B until the whole was condensed,
" and nearly a perfect vacuum established in both
" vessels; yet as the cold water had not entered or touched
" A, that vessel would still retain its heat.

" This idea once started, the rest immediately occurred.
" The vessel A being supposed to be the cylinder, B would
" be the vessel called now the condenser; the water, air, &c.,
" accumulated in B, he immediately saw could be discharged
" or drawn out by means of a pump, or the water might be
" let run out by a pipe more than 34 feet long going downwards,
" and the air might in that case be expelled at a valve
" by filling B with water, provided the descending eduction-pipe
" were shut meanwhile. On the whole, however, he
" preferred the pump. Another difficulty appeared, which
" was the making the piston tight. That could not be done
" with water, as in Newcomen's engines; for that might get
" in and evaporate, and produce steam. He therefore thought
" of wax, oil, and similar substances, as substitutes, knowing
" that they would not evaporate in the heat of boiling water;
" and, for greater security, he proposed to employ the steam
" itself as the acting power on the piston.

" The diameters of the pipes necessary to convey the steam
" into and out of the cylinder, he regulated from those in use.
" The size of the condenser he assumed at random, as he did
" that of the air pump, which it was evident must be larger
" than was necessary to contain the water and probable quantity
" of air. All this passed in his mind in the course of a
" few hours; and in a few days he had a model at work, with
" an inverted cylinder, which answered his expectations, and
" was, as far as he remembers, equal in its properties of
" saving steam and fuel to any he has made since, though
" in point of mechanism much inferior. Very simple cocks

" were employed as regulators or steam-valves, and his air-" pump and condenser were of tin-plate. His cylinder, how-" ever, was good, and of brass, [about] 2 inches diameter and " a foot long; the cocks were turned by hand instead of being " wrought by the engine.

" If Mr. W. is thought worthy of credit in this matter, and " the facts are consequently allowed, where was the mighty " difficulty of putting the invention in execution from still " fewer data than he has set forth in his specification? He " is not so presumptuous as to think that there were not, and " are not, numbers of mechanics in this nation, who, from the " same or even fewer hints, would have completed a better " engine than he did. Mr. Bramah has proved* that he " could, and W. is inclined to believe him. But W. does not " pretend that *any body* could have done it without *thinking* " upon it, nor without much previous knowledge and some " experience of similar things.

" Had W. been content with the mechanism of steam-" engines as they then stood, his machine might soon have " been brought before the public; but his mind ran upon " making engines *cheap* as well as *good*, and he had a great " hankering after inverted cylinders and other modifications " of his invention, which his want of experience in the prac-" tice of mechanics in great, flattered him would prove more " commodious than his matured experience has shown them " to be. He tried, therefore, too many fruitless experiments " on such variations. He wanted experience in the construc-" tion of large machines; that he endeavoured to acquire; " but experimental knowledge is of slow growth, and with all " his ingenuity, *so much boasted to his prejudice*, he was con-" cerned in making some very indifferent common engines. " Other avocations, to him necessary, obliged him to turn his " attention from the subject till he obtained the patent, so " that at that time he had made no advances in the improve-" ment of the mechanism. He therefore thought it proper

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* *i. e.* Given it in evidence.

" to specify only what was his invention, and to leave any
" mechanical improvements he might make, to be secured by
" other patents, if worthy of them.

" His idea, then, was to apply his invention to the steam-
" engines as they existed. For this purpose there was nothing
" else necessary than to shut up the snift, to apply a regulator
" or valve to the opening of the eduction-pipe within the
" cylinder, an air-pump to the outer end of that pipe, and to
" inject into the upper end of the eduction-pipe. If, at the
" same time, the cylinder was defended from the cold of
" the atmosphere, the engine would thus be complete, if the
" weight of the atmosphere were to be employed as the
" acting power; for all the regulators could be easily opened
" and shut by the then existing contrivances, and the air-
" pump rod could be suspended from the working beam.

"If, however, the engine was wanted to receive all the
" advantages of the invention, the cylinder was to be placed
" in a case containing steam, with access for that fluid to the
" upper side of the piston, so that it might act upon it as the
" atmosphere acted in common engines, or in the case just
" stated. And in this latter manner were the engines made
" which he constructed in the beginning of the business; that
" is to say, the cylinders were fixed in a case containing
" steam, with which fluid they were wholly surrounded; and,
" their mouths being open within the case, the steam had
" always access to the upper side of the piston, and was
" admitted to the part below the piston only when the piston
" was rising. The opening from the cylinder into the educ-
" tion-pipe was shut by a valve while the piston was rising
" but when it was required to descend, the valve was opened.
" Those valves were of the sliding kind used in Newcomen's
" engines. The injection was made into the eduction-pipe;
" and the air-pumps, which drew out the water as well as the
" air, were fixed to the bottom of the eduction-pipe, which
" had a valve to prevent regress as usual. There was some-
" times one pump, and sometimes there were two or three, as
" circumstances or the fancy of the moment directed. The
" working beams and working gear were made in the usual

" manner, or nearly so; and in cases where there were boilers " fixed for the common engine, which was superseded, they " were used without alteration.

" These engines, then, differed in nothing from the ancient " ones, except in the application of W.'s principles as set forth " in his specification.

" It was found that the external cylinder, or steam-case, " was very expensive. The method of covering *the cylinder* " *itself* with a lid or cover, (which had been used in some of " the models), and conveying the steam to the lower end of " the cylinder by a pipe, was adopted, and a less expensive " method of applying the envelope of steam was used. Other " kinds of regulators were invented, and the whole mechanism " of the engine was gradually improved, and these improve- " ments have been progressive for the last twenty-one years. " Some of them W. has secured by other patents, but many " of the most essential he has left free, and by means of them " Newcomen's engines have been improved to his loss.

" It will now, it is hoped, appear to the candid that W. has " not wilfully concealed his invention by a false specification, " but has set forth the nature of the same, and the means of " performing it. He has told what he had invented; and it " could not have been expected that he should have described " mechanism already known to all practitioners, or not then " invented.

" W.'s invention is merely a contrivance to prevent cooling " the cylinder, and to make the vacuum more perfect *by con-* " *densing the steam in a vessel distinct from the cylinder itself;* " this is the nature of the invention. The means of keeping " the cylinder warm,—the substitution of the powers of steam " for those of the atmosphere,—of grease, &c., in place of " water to keep the piston tight,—and the drawing out the " air, &c., by means of pumps, are merely aids in performing " the principal object. This ought to be kept in view in " judging of the specification; also that W. supposed it to be " addressed to mechanics and philosophers, and not to the " ignorant."

CHAPTER VIII.

DR. BLACK'S AND PROFESSOR ROBISON'S ACCOUNT OF MR. WATT'S INTRODUCTION TO DR. ROEBUCK — ENTIRE ORIGINALITY OF MR. WATT'S INVENTION — CONFIRMED BY DR. ROEBUCK — WILCKE'S AIR-PUMP ACTING BY THE CONDENSATION OF STEAM — SUBSEQUENT TO MR. WATT'S INVENTION OF THE SEPARATE CONDENSER — HUMPHRY GAINSBOROUGH.

WITH regard to the model of Newcomen's engine belonging to the College of Glasgow, and which has attained so great a celebrity by the results which it was instrumental in producing, we find two entries in the records of that University; the first is as follows:—" University meeting, 25th June, " 1760. Mr. Anderson is allowed to lay out a sum, not exceeding two pounds sterling, to recover the steam-engine " from Mr. Sisson,* instrument-maker at London."

Mr. John Anderson in 1757 succeeded Dr. Dick as Professor of Natural Philosophy in the College; he filled that chair for the long period of thirty-nine years, and was the founder of the Andersonian Institution in Glasgow, which he designed "for Lectures in Natural Philosophy, and in every " branch of knowledge;" and which was endowed by him with valuable philosophical apparatus, a museum, and library. We have already seen from the account given by Dr. Robison, that Mr. Anderson, although " much more popular " than his predecessor, was considered to have " infinitely less knowledge;" a circumstance which may perhaps account for the nearly total oblivion of his name in any of the records connected with the life of Watt. But it appears that he was a

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[*] Of this skilful artificer the learned M. Delambre writes :—" Sisson fit " le quart de cercle de Greenwich, " un autre pour l'Observatoire particulier du Roi d'Angleterre, et le " quart de cercle que Lemonnier " rendit mobile. Sisson soutint à " cet égard l'honneur *et la prééminence* de l'Angleterre."—Delambre, 'Histoire de l'Astronomie 'au dixhuitième Siècle,' p. 237, 1827.

native of Greenock, and brother of one of Mr. Watt's school-companions, and, having been Professor of Hebrew from 1754 to 1757, he doubtless aided in that act of kindly patronage by which Mr. Watt was, at a critical period of his life, protected and encouraged. His employment of the young artisan to repair the little machine which suggested a train of thought leading to the greatest inventions of modern days, certainly gives Mr. Anderson a further claim, even if it be but an accidental one, to have his name associated with the "natural philosophy" of the steam-engine and of Glasgow College.

The model, (as will presently appear), never having worked well, the reason of it being sent to London had probably been a vain endeavour to have its faulty construction amended. Whether Mr. Watt had seen it, during his stay there, in the workshop of Sisson, or how far he may have advised it being brought back to Glasgow, as a subject for further consideration and study, we know not. But the next entry concerning it, in the same records, appears to be this:—"University "meeting, 10th June, 1766. An account was given in by "Mr. James Watt for repairing and altering the steam-"engine, with copper pipes and cisterns, amounting to 5*l*. 11*s*. "The said machine being the property of the College, and "having been in such a situation that it did not answer the "end for which it was made, the Principal is appointed to "grant a precept for payment of the said account, which is "to be stated upon the fund for buying instruments to the "College." *

This, it will be remembered, was after the idea of the separate condenser had "occurred," which was "early in 1765;" and by the repairs and alterations of the "copper pipes and "cisterns" of the machine, its fault of *not answering the end for which it was made*,—(one grievous enough, no doubt, but appertaining to many other machines, both animate and inanimate, in common with it),—had in all probability been effectually corrected. That interesting little model, as altered by the hand of Watt, and preserved in all safety and honour within the precincts of its ancient birth-place, had been appropriately placed beside the noble statue of the Engineer, in the Hunterian Museum;—a sacred relic worthy of such a shrine, and there visited by many a worshipping pilgrim. Such had been, of late years, the felicitous arrangement. But on revisiting the College of Glasgow in January, 1854, "one morn "we miss'd" the model from its apposite home. On inquiry, we found that it had been placed among the apparatus attached to the Natural Philosophy Lecture-room, where, it was alleged, it had dwelt nearly a century ago. As the model, however, belongs to "the College," we hope that this seclusion, so disappointing to the public eye, may be only temporary; and that what might now be fairly said to be "meant for mankind," may not permanently be imprisoned where it can be open to the inspection of comparatively only a few.

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* For these extracts from the University Records we are indebted to the kindness of a learned friend, the Rev. Dr. William Fleming; whose high academic praise it is, that he ably and eloquently fills the Chair once occupied by a Hutcheson, an Adam Smith, and a Reid. See also 'Deeds instituting Bursaries, &c., 'in the College and University of 'Glasgow,' p. 215, 1850.

None of the different accounts which thus remain to us of the date of this, Mr. Watt's greatest invention, fix the precise day on which, to use Dr. Black's happy expression, "this "capital improvement flashed on his mind at once, and filled "it with rapture." According to Robison's recollection, thirty-one years afterwards, it was somewhere about 1765. Dr. Black, writing after the same interval of time, states it as having been "in the beginning of the year 1765." Mr. Watt himself, in his notes on Robison, says "early in 1765;" and the nearest approximation that we can make, from other documentary evidence, to any more precise date, is, that it must have been previous to the 29th of April in that year, as on that day Mr. Watt writes to his friend Dr. Lind, "I have "now almost a certainty of the *facturum* of the fire-engine, "having determined the following particulars: the quantity "of steam produced; the ultimatum of the *lever engine;* the "quantity of steam destroyed by the cold of its cylinder; the "quantity destroyed in mine: and if there is not some devil

“ in the hedge, mine ought to raise water to 44 feet with the
“ same quantity of steam that theirs does to 32, (supposing
“ my cylinder as thick as theirs), which I think I can demonstrate.
“ I can now make a cylinder of 2 feet diameter and
“ 3 feet high only a 40th of an inch thick, and strong enough
“ to resist the atmosphere; *sed tace.* In short, I can think of
“ nothing else but this machine. I hope to have the decisive
“ trial before I see you. Write me to-morrow what you are
“ about, and if any part of what you have to tell me concerns
“ the fire-engine.”

“ His mind,” says Dr. Black, “ became now very much
“ employed in contriving the machinery by which this improvement
“ might be reduced to practice; and he soon
“ planned it to such a degree, that he thought he was ready
“ to make an experiment on a large scale. But here he was
“ stopped by the want of funds; and he found it necessary to
“ associate himself with some person who had money and
“ spirit for such an undertaking, and to participate with him
“ the advantages which might be derived from this invention.
“ He addressed himself to the late Dr. Roebuck, whose spirit
“ for enterprise and improvement in arts was very well
“ known, and the Doctor accordingly received with zeal the
“ opportunity offered to him. A small engine was soon built
“ in one of the offices of Kinneil House, near Borrowstoness,
“ where various trials were made, and some difficulties surmounted,
“ so as to give satisfaction.

“ I must add that I was as much upon a footing of intimate
“ friendship with Dr. Roebuck as with Mr. Watt. The
“ Doctor, too, had no small degree of mechanical knowledge
“ and ingenuity; and was well qualified to perceive and
“ value the talents of Mr. Watt. He had also much experience
“ of the use of common steam-engines, which he employed
“ in working his colliery. He was withal ardent and
“ sanguine in the pursuit of his undertakings, and was therefore
“ a fortunate associate for Mr. Watt. Mr. Watt was a
“ valetudinarian, more or less, ever since I knew him; and
“ his mind was liable to be too much depressed by little cross
“ accidents, or by the necessity of a greater expense than he

" had foreseen; whereas the Doctor was undaunted on such " occasions, and roused Mr. Watt to disregard expense, and " to double his exertions, until the difficulty was overcome. " But Mr. Watt was the sole inventor of the capital improve- " ment and contrivance above mentioned. I remember very " well that it cost me several reasonings and conversations to " inform the Doctor fully of the nature of steam, of the great " quantity of heat, and, consequently, of fuel, necessary to " produce it, and of the importance, therefore, of preventing " the waste of it."

" I was very unfortunate," says Robison, " in two visits I " made to Glasgow during that summer; Mr. Watt being " from home, once at Greenock, seeing his father, who was " ill, and the other time on a survey for a canal. When I " came to town for the winter, I found that Mr. Watt was " again from home, and that he was deeply engaged with his " engine. His situation in life made it imprudent to engage " in great expenses, and he was obliged to look out for an " associate. Most fortunately there was in the neighbourhood " such a person as he wished,—Dr. Roebuck, a gentleman of " very uncommon knowledge in all the branches of civil " engineering, familiarly acquainted with the steam-engine, " of which he employed several on his collieries, and deeply " interested in this improvement. He was also well accus- " tomed to great enterprises, of an undaunted spirit, not " scared by difficulties, nor a niggard of expense. Such a " man was indispensably necessary to one of Mr. Watt's " character;—modest, timid, easily frightened by rubs and " misgivings, and too apt to despond. I do not know who " pointed him out to Mr. Watt. He was well acquainted " with Mr. Watt's talents, and admired them. I believe the " connection was very soon formed. Dr. Black and all Mr. " Watt's friends were happy at seeing so fair a commence- " ment. At this time I had not the pleasure of being known " to Dr. Roebuck." * * * " I believe that Dr. Black was " the chief means of forming the connection between Mr. " Watt and Dr. Roebuck; and I recollect most distinctly " his saying to me, that Watt would have some difficulty in

" managing Dr. Roebuck, who at that time had not become " a complete convert to the doctrine of latent heat. Accord- " ingly, it was so; and Mr. Watt was obliged to yield for " some time to the Doctor's confidence in his own great " experience. The Doctor thought to produce the condensa- " tion, with sufficient rapidity and accuracy, by a very exten- " sive surface; and Mr. Watt knew that it also required " a great quantity of water, or other matter, to receive the " emerging heat. I know that these differences of opinion " retarded the completion of the engine.

" But Dr. Roebuck had too much judgment not to see the " conclusiveness of the experiments by which the doctrine of " latent heat is established, and not to yield to their force; " and everything went on at last to their mutual satisfaction. " Dr. Roebuck knew Mr. Watt's talents, and most liberally " praised them. His timidity, his disposition to despond " when under unforeseen difficulties, and his painful anxiety " and diffidence in himself, were frequently the subjects of " friendly merriment at the Doctor's fireside; and I have " often heard him say, that without his help, and even his " instruction, on many points of the construction, Mr. Watt " could never have gone on. I have even heard him men- " tion some important, but subordinate, parts of the engine " which were of his contrivance. But I never heard him " lay the smallest claim to the leading thought of a hot and " dry cylinder for the piston to work in, and, therefore, a " separate condenser. I never knew him call it 'my engine,' " nor 'our engine,' but uniformly 'Watt's engine,' when he " had occasion to speak of it as distinct from the *old* or " *Newcomen's* engine. I remember Mrs. Roebuck saying one " evening, 'Jamie is a queer lad, and without the Doctor his " 'invention would have been lost: but Dr. Roebuck won't " 'let it perish.' I mention all these trifling things because " I have often heard gentlemen living in the neighbourhood " of Borrowstoness speak of this new project as Dr. Roe- " buck's, in which he was assisted by one Watt, from Glas- " gow. One gentleman in particular, Mr. Graham of Airth, " insisted with me that Dr. Roebuck was the inventor. But

" one day Mr. Graham came home from Falkirk, where he " had seen Dr. Roebuck, and engaged him in conversation " on the subject. He told me that he now saw plainly that " Mr. Watt was the sole author, and said that he would be " at some pains to undeceive some gentlemen of the neighbourhood, who were of the opposite opinion. This was " very natural. Dr. Roebuck was a gentleman of uncommon knowledge in everything of this kind, and considered " as the first judge in all that country of all such matters; " whereas Mr. Watt was an entire stranger.

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" I remember also, that in 1774, or 1775,* after my return " from Russia, I had some conversation with Dr. Roebuck. " The Doctor spoke with some dissatisfaction of Boulton and " Watt. They were now, he said, amassing fortunes from a " project which his misfortunes had obliged him to cede to " them. They seemed to have forgotten that he had suffered " all the anxieties attending the infant project; he had run " all the risk,—and the risk had been very great, both from " the novelty of the thing, and from Mr. Watt's delicate " health, and his timidity under difficulties;—that without " his continual encouragement and support it never would " have succeeded. He had ceded his right on very moderate " terms, and he had expected some remembrance of this. " In this disposition to repine at an opportunity which he " had lost of benefiting himself, it would have been most " natural for Dr. Roebuck to put a high value on any part " that he had had in the discovery; and I listened with some " anxiety to hear if he advanced any claim of this kind, for I " knew that any such thing from Dr. Roebuck would be " received with much deference. But I have the most distinct recollection that he made no claim whatever of this " sort; but, on the contrary, spoke in the highest terms of

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* This date probably was given by Dr. R. in mistake for a later one, as Mr. Watt's Act of Parliament was obtained in May, 1775; after which, though in the same year, it was that he entered into partnership with Mr. Boulton. It was several years before the manufacture of the improved steam-engines, which only commenced in 1775, became in the least degree remunerative.

Watt's ingenuity and inexhaustible resource of in-
tion.*

'he duties of my profession call my attention to a great
iety of very interesting objects. Of all these, my
ɔurite object is practical mechanics. I have, therefore,
ited everywhere for information, and my opportunities
'e been considerable. Understanding most of the lan-
ıges of Europe, I have looked into almost every book
ch treats of such things; and, in particular, I have
rched for every project in mechanics, description of
chines, and schemes of public works. I can recollect
one trace of anything like a separate condenser of
am. This is in a volume of the 'Commentarii de
ebus in Medicinâ et Scientiâ Naturali gestis;' I cannot
recollect the volume, and only remember that it is a
one; (indeed this whole work is of a date posterior to
i9). In this volume there is a short account given of an
pump by M. Wilcke, of Upsal or Stockholm, precisely

'e understand these remarks
Robison to have had reference
ıe stories told by a person of
ıme of Joseph Hately, who,
come into the employment of
toebuck some time after Mr.
had begun to make his experi-
l essays at Kinneil, but having
to give his employer satisfac-
ɿuitted it, or was discharged,
a service of about eighteen
s. He seems to have after-
(16 Nov. 1790) taken out a
for a "Pneumatic fire-engine;"
ould not have been noticed
ıad it not been for a very ab-
fable of which he was the
'; which was to the effect that
ıproved engine had been in-
l not by Mr. Watt, but by Dr.
ıck. This story he circulated
eve of Boulton and Watt's
ion with the infringers of their
rights; the design of it ob-
being, by an allegation of
invention, to "*avoid*" Mr.
patent. Before venturing to
lgate such a creed he had
l,—no doubt wisely, as he
ıt,—till the Doctor's death,
which happened in 1794: and thus he hoped to escape an effectual contradiction. Such folly and audacity, however, were at once exposed, as they deserve always to be; and we have now before us a letter from Dr. R.'s son, Mr. John Roebuck, (to Mr. Watt, 22nd Nov. 1796), in which he says, "I never heard my father in "the smallest degree claim any merit "or pretend to have any share in "inventing or even in improving "upon your engine. On the con- "trary, he always represented the "whole invention to be yours." Also, one from a gentleman who had been clerk to Dr. R. at the time in question, and continued in strict friendship with him from that period to the time of his death; who expresses his astonishment "that Mr. Hately "should pretend to attribute an in- "vention to Dr. Roebuck, which on "every occasion, during a twenty- "seven years' intimate acquaintance "with the Doctor, he had avowed to "me, and to others in my hearing, to "be wholly yours." (Mr. James Warrock to Mr. Watt, 26th Nov. 1796.)

"such as I made when I heard of Mr. Watt's contrivance. "It is mentioned as a thing which the Reviewers had forgotten in its proper time, and they say, '*dudum fabricavit.*' I "mentioned this about a year ago to Dr. Black, when we "were speaking of some curious observations of M. Wilcke "on the cloud which appears in the receiver of an air-pump "when damp air is suddenly rarefied. The Doctor told me, "that when he was yet in Glasgow, he had a pupil of the "name of Williams, or Williamson, from the Mine College in "Sweden; that this person was intimately acquainted in "Dr. Roebuck's family, and, he believed, also with Mr. "Watt; that he was in this country almost three years, and "fully understood all his theory; and he had no doubt that "Dr. Wilcke owed to him all that he had published on that "subject. He thought it equally probable that this project "of an air-pump had transpired in some of our conversations, "it being a thing on which we put no value." * *

The following is evidently the notice intended to be referred to by Dr. Robison, which we here translate from the Latin, in which language it is printed in the Transactions of the Royal Academy of Sciences of Sweden:—

* * * * *

"3. John Charles Wilke, Lecturer on Experimental Philosophy, proposes *a new kind of air-pump*. He makes use "of the well-known property which the steam of boiling "water possesses, of so expanding itself, as to drive out the "air from any space which it fills. Instead, therefore, of "that cylinder, in which, in common pumps, the sucker "moves, he takes a metallic vessel, into which, by means of "a tube, the steam of water, boiling over a fire, can ascend; "by another aperture, the air contained in the vessel (which "he calls a receiver) retires before the steam. The receiver "is joined to a globe, on which a glass bell may be placed, "as in common pumps; and those three apertures of the "receiver, by which the steam enters, the air escapes, and "the globe is connected with it, may be closed by valves or "cocks. The last of them, up to this point, is kept shut. "When the steam, ascending into the receiver, has suffi-

" ciently expelled the air, the cock by which the air had
" escaped is closed, and the receiver is surrounded with cold
" water. The steam, thus condensed, returns, in the form of
" drops, to the vessel whence it came; and the cock which,
" when open, had permitted it to rise, being now closed, a
" vacuum, to a great extent, is formed in the receiver. Then
" the cock by which it is joined to the globe, being opened,
" air will rush into it from the bell. This kind of exhaustion
" may be repeated, till there remains under the bell [no
" more than] a one hundred and thirtieth portion of the air,
" in the machine with which Mr. Wilke made his experiment,
" and which was by no means so perfect as it might be made
" by greater care. Even common air-pumps, as improved by
" Nollet, rarefy air about 300 times; (Wilke takes no notice
" of John Smeaton's pump, mentioned in the Philosophical
" Transactions, vol. xlvii. Art. 69, by which air is said to be
" rarefied 500 or even 1000 times); so that this one, a little
" better made, will easily equal their performance; but its
" principle is, that it will exhaust the air suddenly, not, as
" the common ones do, by degrees: (Nollet and others
" showed how a large receiver could be first emptied of air,
" and applied to the bell, so as to let the air from the
" latter suddenly rush into it). 'But,' it is added, 'as it
" 'needs fire and water, its use is attended with some incon-
" 'veniences.' "[*]

Dr. Robison is not quite accurate in saying that the whole of the 'Commentarii' are of a date posterior to 1769. The work was published in a series of thirty-seven volumes, commencing in 1752, and ending in 1806; with three volumes of 'Supplementa,' 1763-96, and three of Indices, 1770-1793. But it is certain that the passage quoted above is of a date several years subsequent to Mr. Watt's invention of the separate condenser; and the circumstances through which it happened that Mr. Wilcke was even so early in possession of the idea of an air-pump, such as that described, are, no doubt, very well explained by Dr. Robison.

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[*] 'Kongl. Vetenskaps Academiens 'Handlingar för Aor 1769,' vol. xxx. &c. *i. e.*, Acta Academiæ Reg. Sc. Suecicæ, anni 1769, vol. xxx. (Trimestre primum), printed in the 'Commentarii de Rebus in Scientiâ 'Naturali et Medicinâ gestis,' voluminis xviii. pars I. - Lipsiæ, 1772.

Although our readers may probably be of opinion that it does not require such notice, we may here advert to a story told in a recent Life of Gainsborough the artist,* concerning his brother Humphry. This genius was the brother, not only of the celebrated painter, but also of a certain "scheming "Jack," noted for the mechanical delusions by which he was influenced, including the usual one of flying in the air on artificial wings; which he attempted to practise somewhat after the manner of the mechanist in Rasselas, and with a similar result; but with the top of a summer-house for his promontory, and a ditch for his lake, "out of which he was drawn amidst "shouts of laughter, half-dead with fright and vexation."

Humphry was largely endowed with the family fancy for "scheming," and the inventiveness of his mind was extolled by Mr. Edgeworth. He is said by Mr. Fulcher (p. 13) to have "settled as a dissenting minister at Henley-upon-"Thames;" although it appears from a letter at p. 103 of the same volume, that his business was that "of collecting "the tolls upon the river." In this arrangement it is satisfactory to learn that the Rev. gentleman's "mechanical con-"trivances were the employments of his leisure hours, and "were never suffered to interfere with his sacred duties."

This being premised, "We may mention," says Mr. Fulcher, "that his experiments upon the steam-engine were far "in advance of his time. Indeed, it was stated by his family "and friends, that Watt owed to him one of his great and "fundamental improvements, that of condensing the steam "in a separate vessel. Certain it is, that Mr. Gainsborough "had constructed a working-model of a steam-engine, to "which his discoveries were applied, and that a stranger, "evidently well acquainted with mechanics, and supposed to "be connected with Watt as an engineer, was on a visit at "Henley, and called upon him, to whom he unsuspectingly

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* Life of Thomas Gainsborough, R.A., by the late George Williams Fulcher. Edited by his Son. London. 1856.

"showed his model and explained its novelties. His relatives have assured the Author that such was the fact, and "that the circumstance of having thus lost the credit of his "discovery, made a deep and melancholy impression upon "his mind. The truth of this statement receives also strong "corroboration from the remarks of Thicknesse, who says,— "'Mr. Gainsborough' (the painter) 'gave me, after the death "'of his clergyman brother, the model of his steam-engine: "'that engine alone would have furnished a fortune to all "'the Gainsboroughs and their descendants, had not that "'unsuspicious, good-hearted man, let a cunning, designing "'artist see it, and who surreptitiously carried it off in his "'mind's eye.' Watt obtained his first patent for performing condensation in a separate vessel from the cylinder, in "1769; it was renewed in 1775. Humphry Gainsborough "died in 1776."*

Such is the tale told by Mr. Fulcher, in the hope, we suppose, of persuading his readers that Mr. Humphry Gainsborough had anticipated James Watt in one of his grandest inventions for the improvement of the steam-engine;—nay, that James Watt, not only the greatest mechanical inventor that ever lived, but "the most scrupulous of men where the "inventions of others were concerned," had actually palmed off upon the world as his own—had obtained a patent, and a further extension of that patent by Act of Parliament, for an invention previously made, and known to him to have been made, by the dissenting minister and toll-collector of Henley-upon-Thames! Yet, when we look for the evidence on which such a charge is made, what do we find? The nature of the "experiments upon the steam-engine" alleged to have been made, or of the "discoveries" stated to have been applied to the working model, is not in a single instance specified;—of the "family, friends, and relations," spoken of as upholding the credit of the tale, not one individual is named;—of the mysterious "stranger" himself, "evidently "well acquainted with mechanics," *stat nominis umbra*;—and his very "connection with Watt as an engineer" was, it seems, only "supposed" to exist!

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* Fulcher, pp. 18, 19.

As for the Thicknesse, whose remarks are introduced as a "strong corroboration" of the whole, he "published," says Mr. Fulcher, "a brief memoir, written in one day, of which "we need not say more here," he continues, "than that it "deservedly enjoyed a fame of equal duration." (Pref. p. iii) Of the same person's autobiography, Mr. Fulcher adds that therein "his spites, his bickerings, his disappointments, the "ill-natured things he did, the mistakes he made, the worth "he insulted, are recorded with a minuteness which his most "malignant enemy might have envied." (p. 42.) Mr. Thicknesse was therefore a very proper herald to select for that engine which "alone would have furnished a fortune for all "the Gainsboroughs and their descendants,"—a fitting Daniel come to judgment on the "cunning, designing artist," whom the "unsuspicious, good-hearted man" allowed to see it, and "surreptitiously to carry it off in his mind's eye."

But, fortunately, Mr. Fulcher's story is not original with him; nor is a test of its truth now to be applied to it for the first time.

Jabez Hornblower, who, after having been long employed as a stoker in Messrs. Boulton and Watt's manufactory at Soho, was, in the end of the last century, convicted of gross piracy of Mr. Watt's invention, employed a portion of the leisure which fell to his lot in the King's Bench Prison in writing a first edition of the same fable, which was published in Gregory's Mechanics. Mr. Hornblower, however, with less caution than Mr. Fulcher, did not altogether evade the mention of any name or detail to authenticate his tale; but appealed, in proof of it, to a conversation said to have been held with Mr. Samuel More, the very respectable Secretary to the Society of Arts.

Now, in the trial of the cause, Boulton and Watt *v.* Bull, in the Common Pleas, 22nd June, 1793, Mr. More was, it happens, examined as a witness. He was asked, "You must "have seen and known a vast number of machines of various "kinds;—Did you ever meet with the application of those

" principles Mr. Watt has applied to the fire engine before you " knew Mr. Watt's engine?" And upon oath he answered, " My situation in life leads me to see a vast many mechanical " contrivances, and my inclination leads me to look into " them. I take it to be the most useful engine that has ever " been brought forward by the mind of man; I have considered it attentively; *I do declare I never saw the principles " laid down in Mr. Watt's specification either applied to the " engine previous to his taking it up, nor ever read of any such " thing whatever.*"

If it be true,—although of this we have no proof beyond Hornblower's assertion,—that Mr. More had inspected Mr. Humphry Gainsborough's "working-model" to which his precious "discoveries" were "applied," this only makes his evidence in favour of the entire novelty as well as originality of Mr. Watt's steam-engine the more conclusive. Mr. Humphry Gainsborough's opinion of the value of his own machine, as compared with that of Watt, appears, no doubt, to have been tolerably good; for "Suppose," writes Mr. Boulton to Mr. Watt in 1775, "another ingenious man starts up with " another new discovery that should prove to be seven times " better than the common engine, whilst ours is only three " times, what then becomes of all the fabric we have raised, " and of the visionary profits? And let me tell you that " there is great probability of it, for there is a very ingenious " man at Henley-upon-Thames, who asserts that he hath " made such a discovery." The person here alluded to,—who would have been very ingenious indeed if the ratio of seven to three in favour of his steam-engine against that of Watt had only proved to be true!—was no doubt Gainsborough;—as in a subsequent letter, believed to have been written in 1776, Mr. Boulton talks of "Tubal-Cains, or Watts, " or Dr. Fausts, or Gainsboroughs, arising with serpents like " Moses', that devour all others."

Humphry Gainsborough's serpent, however, did not actually devour the others; which would rather have baffled its powers of digestion. He himself, (Gainsborough, not the serpent!), is stated to have died in 1776, under a "deep and "melancholy impression on his mind" of having failed; but very possibly retaining that conceit of the superiority of his own "discoveries" which seems to some extent to be habitual with projectors, but especially with unsuccessful ones. Those who, like Newton or Watt, do really make great scientific discoveries which truly and widely enlighten and benefit mankind, and deservedly command the admiration of the world, are usually less sanguine, and always, we venture to believe, more modest. Stuart, in his History of the Steam-Engine, calls Hornblower's story, quoted above, an "extraordinary "and disingenuous statement;" and the friends of Mr. Fulcher, whose publication is a posthumous one, must regret that, after the interval of more than half a century, he should have been deluded into giving renewed currency to anything so groundless, and, we will venture to add, so absurd.

CHAPTER IX.

HISTORY OF THE STEAM-ENGINE BEFORE THE TIME OF WATT — ÆOLIPILES — ANTHEMIUS — GERBERT — PORTA — RIVAULT — SOLOMON DE CAUS — MARQUIS OF WORCESTER — HIS 'CENTURY OF INVENTIONS' — QUESTION WHETHER HE EXECUTED HIS APPARATUS — HIS ACT OF PARLIAMENT — BEAUFORT MSS. — ROLLOCK'S 'PANEGYRIC' — TRAVELS OF COSMO DE MEDICIS.

As we are now arrived at that important epoch of Mr. Watt's life when he made the first, the greatest, and the most prolific of all his mighty inventions connected with the steam-engine, it is necessary that we should give some explanation of the state in which he found that machine, as then employed in imperfectly draining some collieries and mines in Great Britain, although not otherwise made available in either this or any other country. Without a brief historical sketch such as this renders necessary, many of our readers would find it difficult either to follow the steps by which Mr. Watt ascended in his successive inventions, to understand their importance, or to appreciate their beauty; and we venture to believe that it is possible to communicate all that is on the present occasion needful to be known on this part of our subject, without perplexing our narrative by details either very numerous, or at all obscure.

The earliest instance of a machine in which steam was deliberately used to generate motion, is, it seems to be generally admitted, the Æolipile,—Æoli-pila, or ball of Æolus,—such as is delineated and described by Hero of Alexandria, in his Pneumatica, or Spiritalia,* about 120 B.C. This æolipile was a hollow ball of metal, moveable on external axes working in sockets, and fitted with one or more tubes issuing from it horizontally, closed at their ends, but with an opening in their sides. This ball being partially filled with water, and placed over a fire, the re-action of the steam, rushing with violence from those openings, caused it to revolve with more or less rapidity according to the force of steam employed. The machine has been constructed of several forms, and has often served purposes of ingenious amusement. In point of practical utility, it is recommended by Branca, in his work entitled 'Le Machine,' published at Rome in 1629, to be used to produce a rotatory motion, by acting on the pinions of a wheel. It has also been employed instead of bellows, directing a strong current of steam on the fire, in place of a blast of air. Sir Hugh Plat, at p. 23 of his 'Jewel House of 'Art and Nature,' (printed at London in 1653), gives a particular description of one which he calls "A round ball of " copper or Latten, that will blow the fire very strongly, " onely by the attenuation of water into air; which device " may also serve to perfume with;" and he annexes a woodcut of it.

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* A curious treatise, which, along with his other works, is to be found in the Mathematici Veteres, Gr. et Lat., Par. 1693, fol.

But the most singular details as to an instrument of this sort with which we have met, are given in the following passage, taken from Plot's Staffordshire:—" Yet there are many " old customs in use within memory, of whose originals I " could find no tolerable account, that possibly might commence as high as these times; such as the service due from " the Lord of Essington in this county [Stafford] to the Lord " of Hilton, about a mile distant, viz. that the Lord of the " manor of Essington shall bring a goose every New-year's-" day, and drive it round the fire in the hall at Hilton, at " least three times, (which he is bound to doe as mean lord), " whil'st *Jack* of *Hilton* is blowing the fire. Now, *Jack* of " *Hilton* is a little hollow image of brass of about 12 inches " high, kneeling upon his left knee, and holding his right " hand upon his head, * * * having a little hole in the place " of the mouth, about the bigness of a great pin's head, and " another in the back about ⅝ of an inch diameter, at which " last hole it is fill'd with water, it holding about 4 pints " and ¼, which, when set to a strong fire, evaporates after " the same manner as in an æolipile, and vents it self at the "smaller hole at the mouth in a constant blast, blowing the "fire so strongly that it is very audible, and makes a sensible "impression in that part of the fire where the blast lights, as "I found by experience, May the 26th, 1680."*

A story is told by Agathias, in his history of Justinian, of a trick played by Anthemius, the famous architect of the church—now the mosque—of St. Sophia at Constantinople, which, amidst all the vagueness and probably ignorance of the historian, seems to indicate some knowledge, on the part of its contriver, of the forcible effects of steam. Anthemius and Zeno the rhetorician occupied contiguous houses; and in a dispute about their walls or windows, the learning of the mathematician was defeated by the eloquence of the orator. In order to revenge himself, Anthemius betook himself to the practice of such arts as his knowledge of science could suggest; and among other devices, more ingenious than hurtful, by which he sought to disturb the quiet of his neighbour, was one thus recorded by Gibbon:—"In a lower room, "Anthemius arranged several vessels or cauldrons of water, "each of them covered by the wide bottom of a leathern tube, "which rose to a narrow top, and was artificially conveyed "among the joists and rafters of the adjacent building. A "fire was kindled beneath the cauldron; the steam of the "boiling water ascended through the tubes; the house was "shaken by the efforts of imprisoned air, and its trembling "inhabitants might wonder that the city was unconscious of "the earthquake which they had felt!"†

William of Malmesbury describes as being preserved in the Cathedral of Rheims, among other proofs of the mechanical skill of Gerbert, (afterwards Pope Sylvester II., who died A.D. 1003), a hydraulic organ, blown "by the violence of boiling "water."‡

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[*] Nat. Hist. of Staffordshire, by Robert Plot, LL.D., p. 433, edit. Oxford, 1686. At plate xxxiii. of that work there is an engraved likeness of *Jack*, to which we refer those of our readers who are curious in such matters.

[†] Decline and Fall of the Roman Empire, ch. xl.

[‡] Willielm. Malmesbur. de gestis Regum Anglorum, Lib. ii.; inter Rer. Anglic. Script. ed. Lond. 1596, fol. 36, *verso*.

Baptista Porta, a Neapolitan gentleman who devoted his life to researches in chemistry and natural philosophy, in which he displayed remarkable ingenuity, and distinguished himself by inventing the magic lantern, has left us an account, in a work published in 1601,* of some curious experiments on the power of steam, on its condensation, and on its relative bulk as compared with water. In one of them, a vacuum is distinctly formed by condensation, and water is forced up into it by the pressure of the atmosphere; and although this appears, both from his description and from the rude wood-cut which accompanies it, to have been performed on the scale not of any large engine for raising water, but only of a small philosophical apparatus, still the novel principle is there clearly pointed out, and made available to any of his readers. In another experiment, a retort has its neck inserted in a cistern which is nearly filled with water; the water in the retort is then made to boil, and the steam, pressing on the water in the cistern, forces it up through a tube fixed in its lid.

David Rivault, Seigneur de Flurance, near Laval, in France, in a treatise on the Elements of Artillery, which he published in 1605, and of which a second edition, containing an additional fourth book, appeared in 1608,† describes the power of steam in bursting a strong bomb-shell, partly filled with water, then tightly plugged, and set on a fire. But here, with a power of very great destructiveness, there is evidently a total want of any means of moderating, or almost of estimating, that dangerous force. On behalf of M. Rivault, accordingly, our neighbours on the other side of the Channel,—who cannot in general be accused of understating the rights which they may suppose their country to possess to any share in the progressive invention of the steam-engine,—prefer no claim. This they reserve for two others of their countrymen, Solomon De Caus and Denys Papin, who also flourished in the seventeenth century, the one in its beginning, and the other at its close; of each of whom, and their respective inventions or discoveries, we shall treat in due chronological order.

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* Pneumaticorum libri tres: cum duobus curvilineorum elementorum (printed at Naples), 4to. It was translated into Italian, and published, also at Naples, with the title 'I tre 'libri de' Spiritali,' 1606, 4to.

† The title of his book is 'Les Ele'mens de l'Artillerie, concernans tant 'la premiere inuention et theorie, 'que la practique du Canon. Par le 'Sieur de Flurance Rivavlt. A Paris, 'chez Adrian Beys, ruë Sainct 'Jacques, ioignant la Rosse Blanche, 'M.DC.V.'

The contrivance described and figured by Solomon De Caus is as follows:—Take a strong hollow copper globe, with a cock near the top to admit water, and through the middle of the top a pipe fixed, with its lower end reaching nearly to the bottom of the globe, without quite touching it; fill the globe with water through the cock, close it firmly, (the pipe, however, remaining open), and put it on the fire; then the heat, acting upon the globe, will make all the water ascend through the pipe.

The merit of such a toy, which is little more than a repetition of the apparatus already described by Porta, it might be rather difficult to estimate. We are very willing that it should have all the benefit of the rhetorical talent of the most able of its panegyrists, the late M. Arago, who says:—" The " apparatus of Solomon De Caus, that metal shell in which " a moving power almost indefinitely great is generated by " means of a faggot and a match, will always make a noble " figure in the annals of the steam-engine." Still we cannot but remember that for all purposes of practical utility it has proved to be valueless; and that if, instead of " in the annals " of the steam-engine," M. Arago had said, " in annals previous to those of the steam-engine," he would more exactly have described the period to which a contrivance at once so simple, so harmless, and—we must be pardoned for adding—so useless, properly belongs.

The name next in the series of early " students of steam," is that of Edward, second Marquis of Worcester; in whose 'Century of Inventions,' first published in 1663, occur the following curious articles:—

" 68. An admirable and most forcible way to drive up " water by fire, not by drawing or sucking it upwards, for " that must be, as the philosopher calleth it, *Intra sphaeram*

" *activitatis*, which is but at such a distance. But this way
" hath no bounder, if the vessels be strong enough; for I
" have taken a piece of a whole cannon, whereof the end was
" burst, and filled it three quarters full of water. Stopping
" and scruing up the broken end, as also the touchhole, and
" making a constant fire under it, within 24 hours it burst
" and made a great crack. So that having a way to make
" my vessels, so that they are strengthened by the force
" within them, and the one to fill after the other, I have seen
" the water run like a constant fountaine-stream forty foot
" high; one vessel of water rarified by fire driveth up forty
" of cold water. And a man that tends the work is but to
" turn two cocks, that one vessel of water being consumed,
" another begins to force and re-fill with cold water, and so
" successively, the fire being tended and kept constant, which
" the selfsame person may likewise abundantly perform in
" the interim between the necessity of turning the said cocks."

" 98. An engine so contrived, that working the *primum*
" *mobile* forward or backward, upward or downward, circularly
" or corner-wise, to and fro, streight, upright or downright,
" yet the pretended operation continueth, and advanceth
" none of the motions above-mentioned, hindering, much less
" stopping the other; but unanimously and with harmony
" agreeing, they all augment and contribute strength unto
" the intended work and operation: and therefore I call this
" *a semi-omnipotent engine*, and do intend that a model thereof
" be buried with me.

" 99. How to make one pound weight to raise an hundred
" as high as one pound falleth, and yet the hundred pound
" descending doth what nothing less than one hundred pound
" can effect.

" 100. Upon so potent a help as these two last-mentioned
" inventions, a waterwork is by many years' experience and
" labour so advantageously by me contrived, that a child's
" force bringeth up an hundred foot high an incredible
" quantity of water, even two foot diameter, so naturally,
" that the work will not be heard even into the next room;
" and with so great ease and geometrical symmetry, that

"though it work day and night from one end of the year to "the other, it will not require forty shillings reparation to "the whole engine, nor hinder ones day-work. And I may "boldly call it *the most stupendious work* in the whole world: "not onely with little charge to drein all sorts of mines, and "furnish cities with water, though never so high seated, as "well to keep them sweet, running through several streets, "and so performing the work of scavingers, as well as furnishing the inhabitants with sufficient water for their private "occasions, but likewise supplying rivers with sufficient to "maintaine and make them portable from towne to towne, and "for the bettering of lands all the way it runs; with many "more advantageous, and yet greater effects of profit, admiration, and consequence. So that deservedly I deem this "invention to crown my labours, to reward my expences, "and make my thoughts acquiesce in way of further "inventions."

In these extracts are contained the principal reasons for posterity supposing the Marquis to have been acquainted with the power of steam, and able to apply it to some useful purpose. It is true that in the same extraordinary work, if we are to believe its noble author, many great inventions of more modern days, as well as some which still lie hid in the future, were anticipated. Within the compass of a few very small duodecimo pages, the Marquis enumerates "A way how to "make a Boat work itself against Wind and Tide, yea, both "without the help of man or beast;"—"How to make a "Pistol to discharge a dozen times with one loading, and "without so much as once new Priming requisite;"—"How "to make a man to fly; which I have tried with a little Boy "of ten years old in a barn, from one end to the other, on "an Hay-mow;"—"A Watch to go constantly, and yet needs "no other winding from the first setting on the Cord or "Chain, unless it be broken;"—"An Engine whereby one "man may take out of the water a Ship of 500 Tun, so that "it may be calked, trimmed and repaired without need of "the usual way of stocks, and as easily let down again;"—"An Instrument whereby an ignorant person may take any-

"thing in Perspective, as justly, and more than the skilfullest "Painter can do by his eye;" &c. &c. &c.

All of these, and of the ninety other articles of which the 'Century' is made up, wanted only one condition to be complied with by their author, to satisfy the world that they were not the mere idle dreams of a mechanical visionary, or the impudent boasts of a pseudo-scientific braggart. But that condition is certainly an important one; viz. that he should have executed all, or at least some of the more important of the various machines which he thus describes. And on this point, in the case of the Marquis, there is unfortunately considerable room for doubt; although the little 'Century,' crowing like a game-cock to the last, closes with an account of his "meaning to leave to Posterity a Book, "wherein under each of these Heads the means to put in "execution and visible trial all and every of these Inventions, "with the shape and form of all things belonging to them, "shall be printed by Brass-plates." This was published in 1663, and the Marquis lived for four years afterwards; but, as the promised work never appeared, it is perhaps not very unfair to suppose, as some authors have done, that he either was unable, or never seriously intended, to make such a further publication.

Still it is but just towards his memory to mention some circumstances, which, at least in so far as the "water-commanding engine" is concerned, seem to afford grounds for supposing that, whatever might be the true nature of the power by which it acted, or of the effects which it was able to produce, such an engine was actually constructed and was set to work.

On the 3rd of April, 1663,—the same year in which, as already stated, appeared the 'Century of Inventions,'—a Bill was brought into Parliament "to enable Edward Marquess "of Worcester to receive the benefit and profit of a water-"commanding engine by him invented; one tenth part "whereof is appropriated for the benefit of the King's "Majesty, his heirs and successors," during a term of ninety-nine years; and this Bill was passed into an Act on the 12th of May following, not, as Lord Orford erroneously supposed, on the simple affirmation by the Marquis of his having made such a discovery, but after repeated meetings of committees on the subject, at which several amendments were made on the Bill.

Mr. Partington is not quite accurate when he says, in the Preface to his edition of the 'Century of Inventions,' published in 1825, " On the 3rd of April, 1663, a Bill was brought " in for granting to him [*i. e.* the Marquis] and his successors " the whole of the profits that might arise from the use of an " engine, described in the last article in the 'Century.' " The following history of the date of the introduction of the Bill, and of its progress through Parliament, which we have taken from the Journals of the respective Houses, will, we believe, be found a more correct one.

The Marquis of Worcester's Engine Bill was brought into the House of Lords, and there read a first time, on the 16th of March, 1663.

Bill read a second time 19 March, and referred to a Committee of twenty-two Peers.

The Committee reported certain alterations on the Bill, which were read twice, and the Bill was re-committed, 28 March.

Further report from the Committee, of a proviso to be added: proviso read twice and agreed to, and Bill ordered to be engrossed, with the proviso, 30 March.

Bill read a third time, and passed, 31 March.

Sent to the House of Commons, 2 April.

Read a first time in the House of Commons, 3 April.

Read a second time, and referred to a Committee of fifty-one members, 4 April.

Committee reported several amendments, which were agreed to, and further proviso recommended, 13 April.

Bill with amendments and proviso agreed to, 5 May; and Lord Herbert directed to carry the same up to the Lords.

Bill with amendments brought up to the House of Lords, 7 May.

The Lords acquaint the Commons that they agree to the amendments and alterations in the Bill; message received by the Commons, 12 May.

The Royal Assent given by Commission to the Act, 3 June, 1663.

It will thus be seen that the Act in question was not passed without formal, and apparently careful deliberation; though we still are uninformed as to how far evidence may have been called for, before either of the Committees, as to the reality and the specific particulars of the invention affirmed to have been made. Besides the passing of the Act, and the publication of the 'Century,' the principal circumstances that seem to show that the Marquis did more than merely imagine the construction of such an engine, are the following:—

(1.) It is expressly provided in the Act, "that a model "thereof [*i. e.* of the engine] be delivered by the said Mar-"quess or his assigns, to the Lord Treasurer or Commis-"sioners for the Treasury for the time being, at or before the "nine-and-twentieth day of September, one thousand six hun-"dred sixty-three, and be by him or them put into the "Exchequer and kept there." Unfortunately, we are not in a condition to prove that this model ever was so deposited. The Act was passed prior to the publication of the 'Century,' for in the Dedication prefixed to the latter, "To the Right "Honourable the Lords Spiritual and Temporal, and to the "Knights, Citizens, and Burgesses of the Honourable House "of Commons, now assembled in Parliament," the Marquis speaks of "the Act of the Water-commanding Engine (which "so chearfully you have past)." Yet in the whole course of the work he does not say either that the model had been deposited as directed, or that the engine was in course of construction on a great scale; although he does speak very confidently of the great feats he intended to perform, with the help of one "Caspar Kaltoff's hand," an "unparallelled "workman both for trust and skill, who hath been these five-"and-thirty years as in a school under me imployed, and still "at my disposal, in a place by my great expences made fit "for publick service;"—expenses which he afterwards estimates at 10,000*l.* His expectations of realising a fortune by his engine were evidently exuberant; and, with a heroic boldness not unworthy of the rest of his character and proceedings, he professes his design of first paying his debts, next of settling a competency to himself to live according to his birth and quality, and lastly, of dedicating the rest to the service of his king and country; who, however, fared little the better for that "bright reversion!"

(2.) In a letter to the Marchioness of Worcester from her confessor, dated 1670, which was three years after the death of her lord, the writer remonstrates with her ladyship for allowing her thoughts to be too much set "on the title of "Plantagenet, and of disposing yourself for that greate dig- "nity by getting of greate sums of money from the King to "pay your deceased lord's debts, and enriching your selfe by "the great machine and the like." All of which ideas the priest, Walter Travers, declares to be motives employed by the devil, "to make his suggestions the more prevalent:" very piously advising the Marchioness, "insteede of temporall, "to seeke after eternall riches and honors," but very ungallantly adding, "which your age doth assure you are not "far off."

Along with this letter may be taken another still more curious document, preserved, like it, by the Beaufort family, and published in 1825 in Mr. Partington's edition of the 'Century of Inventions;' it is entitled, "*The Lord Marquesse "of Worcester's ejaculatory and extemporary thanksgiving "Prayer, when first with his corporal eyes he did see finished "a perfect trial of his Water-commanding Engine, delightful "and useful to whomsoever hath in recommendation either know- "ledge, profit, or pleasure;*" and begins as follows:—"Oh! "infinitely omnipotent God! whose mercies are fathomlesse, "and whose knowledge is immense and inexhaustible; next "to my creation and redemption I render thee most humble "thanks from the very bottom of my heart and bowels, for "thy vouchsafing me (the meanest in understanding) an "insight in soe great a secret of nature, beneficent to all "mankind, as this my water-commanding engine. Suffer me "not to be puffed upp, O Lord, by the knowing of it, and "many more rare and unheard off, yea unparallelled inventions, tryals, and experiments," &c.

Supposing this prayer to have been really composed or offered up by the Marquis, it seems at least conclusive as to his own genuine belief in the wonders he asserted himself to have achieved; as he cannot for a moment be supposed to have been so abandoned, as, in so very deliberate and solemn a manner, to have called on his Maker to witness a lie.

(3.) In one or two copies of the first edition of the 'Century,' there occurs, as a sort of Appendix, a description of "a stupendious Water-commanding Engine, boundless for "height or quantity, requiring no external or even additional "help or force, to be set or continued in motion, but what "intrinsically is afforded from its own operation, nor yet the "twentieth part thereof," &c. &c. It is introduced by a preface, and concludes with a Latin elogium and English panegyric, "composed, through duty and gratitude, by an "ancient servant of his Lordship, (James Rollock), who hath, "for 40 years, been an eye-witness of his great ingenuity, "indefatigable pains, and vast expenses *in perfecting, for "public service*, not only this most stupendious Water-commanding Engine, but likewise several other rare, useful, "and never formerly heard of mathematical conclusions, of "which he hath owned a Century, and thereunto I refer you; "though *this* alone were enough to eternalise his name to all "ages and future times," &c. &c. The panegyric is headed, "A Panegyrick to the Right Honorable Edward Lord Marquess of Worcester, upon his stupendious and never sufficiently-commended Water-work," and is as follows:—

"I know mean subjects need a skilful pen
"To stretch their worth on Tenter-hooks, but when
"A Theme falls out so pregnant, who can chuse
"But strain his vulgar Wit to prove a Muse?

"Come, fainting Pilgrim, lay here down thy pack;
"And, while thou rests thy wearied limbs, look back
"Upon this Pageant, the Embleme of his mind
"Whose Art and Skill hath this our Age refined.

" Here little *David* curbs the Gyant's brood,
" Small drops of Rain contend with *Noah's* flood;
" One weighs a thousand coming down apace,
" Weighs but himself when he hath run his race.

" The Heavens admire, the Centre stands amazed,
" To see such Streams by so small Forces raised.—
" Great is the Work, but greater is the Fame
" Of that great Peer, who did invent the same.

" What Force or Strength can do, is in his reach;
" His long Experience, Costs and Charges teach:
" What *Greeks* nor *Romans* ere could do, this day
" Our noble Britain here hath found the way.

" If Ages past had bred you, we had seen
" Your Glorie's current run a bigger stream;
" But Art and Envy meeting face to face,
" Like *France* and *Spain*, dispute who shall take place.

" None but Ignoble Minds love to detract
" From th' honour due to such a noble act:
" On then, that After-ages may relate
" Your Service done to Country, King, and State.

" And though that envious Spirits spit their gall,
" Your Noble Deeds are so well known to all,
" As if their malice should take from your Praise,
" Your own deserts will crown your head with Bayes."

The Latin elogium is much to the same purpose, and precedes the panegyric. It must be confessed that the romantic address of Mr. Rollock bears a somewhat close resemblance to the mythical style of the Marquis; the man having been evidently infected by what cruel critics might term the *vapouring* of the master. But, on the other hand, the expressions in the third stanza are wonderfully descriptive of the powerful action of steam in raising water, as well as of its condensation when its work is done.

(4.) In the translation of the Travels in England of Cosmo de Medicis, Grand Duke of Tuscany, published in 1821, it is stated that "on the 28th May, 1699, his Highness saw at "Vauxhall an hydraulic machine, invented by my Lord "Somerset, Marquess of Worcester. It raises water more

" than forty geometrical feet, by the power of one man only; " and in a very short space of time will draw up four vessels " of water, through a tube or channel not more than a span " in width."

The two accounts of the performances of the engine, the one by the Marquis, and the other by the Duke, or his Secretary, (the celebrated Magalotti), who wrote the Journal, are, in the essential point of numerical appreciation of the power, almost *verbatim* the same: and it is not improbable that, to ensure greater accuracy, the one might be copied from the other. This, however, we have been led to imagine solely from their extraordinary similarity, and from our not having met with a description of the engine in any other contemporary work.

So hard is it to discover, from such accounts, the true state of the case, that on the question of Lord Worcester's execution of any steam-engine, there has always prevailed great diversity of opinion. Nay, we even find one author, of very considerable ingenuity, and of extensive though not always accurate research, in one of his works thinking it clear, for various reasons which he assigns, that this hydraulic machine must have been some species of steam-engine; and, probably, the identical " most stupendious Water-commanding " Engine:"* while in another work, published not long before, he had said that the "'Century of Inventions' is " called by Walpole, *with much truth*, an amazing piece of " folly," and had unmercifully ridiculed " the overwhelming " quackery of the Marquis of Worcester, and the absurd " extravagance of his pretensions." †

We must not omit the tradition which attributes the origin of the steam-ideas of the Marquis to the period of his imprisonment in the Tower of London. His captivity there, which was of several years' duration, began in 1665, when he was arrested while on a mission from Charles II., who was then residing at the Court of France, and had sent him over to England to procure money and secret intelligence; articles of both of which the exiled monarch was at that time very destitute. It is said that the Marquis, "in those deep solitudes and awful cells," one day observed the lid of the pot in which his dinner was cooking suddenly rise, forced up by the vapour of the water which the fire had heated; or, in other words, *by steam.* "Then it occurred to him that the same "force which had lifted the lid might become, in certain circumstances, a useful and convenient moving power:" and hence—so runs the story—arose the 'Century of Inventions,' with its steam-engine all ready-made and acting;—at least in the mind of its contriver!

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* Historical and Descriptive Anecdotes of Steam-engines, by Robert Stuart. London, 1829, vol. i.

† Descriptive History of the Steam-engine, by Robert Stuart. London, 1824.

CHAPTER X.

COMPARATIVE CLAIMS OF SOLOMON DE CAUS AND THE MARQUIS OF WORCESTER — NATIONAL CONTROVERSY — LETTER FROM MARION DE L'ORME PUBLISHED BY MISS COSTELLO — EXPOSURE OF A FRAUDULENT IMPOSTURE — PHILOSOPHICAL DISCOVERIES OF THE SEVENTEENTH CENTURY — GALILEO — TORRICELLI — PASCAL — OTTO DE GUERICKE.

THE comparative claims of Solomon De Caus and of the Marquis of Worcester have been a favourite subject of discussion with many writers in both France and England, the countrymen of the one and of the other respectively. We say their countrymen; for, although De Caus published his book 'Les Raisons des Forces Mouvantes' at Frankfort, and was for some time in the service of Henry, Prince of Wales, at Richmond, and afterwards of the Elector Palatine at Heidelberg, who married the Princess Elizabeth of England, he yet writes in French, calls himself, in the Dedication of the first part of that work to Louis XIII., a subject of that monarch, and is also styled his subject in the Privilege granted to his publication. But his principal works were published, either in London, ('La Perspective avec la Raison 'des Ombres et Miroirs, 1612'), or "beyond the Rhine," ('Les Raisons des Forces Mouvantes, 1613, en la boutique 'de Jan Norton, *Libraire Anglois*'); and it is sufficiently singular that the distinguished patronage which he frequently and gratefully acknowledges was conferred on him by the Royal Family of this country; which, in all that relates to mechanical science, seems then, as now, to have asserted a proud pre-eminence.

In the national competition as to those two ingenious projectors, De Caus had clearly the priority in point of time, by a whole half-century. But then he is not even alleged ever to have applied his hollow ball and tube, or,—to dignify them by a name which they could hardly claim,—his boiler and steam-pipe, to any purpose of utility; and in all probability he never either executed them on a great scale, or attempted to regulate the force which on a small scale he may have been able so to exert. The engine devised by Lord Worcester, on the other hand, if we are to believe the concurrent testimony of his own description and prayer,—of the correspondence between his widow and her confessor,—of the panegyric of his servant Rollock, and of the account given by Duke Cosmo de Medicis and his Secretary Magalotti,—would appear to have been at last executed on a scale large enough to produce very considerable hydraulic effects; and, although we must probably ever remain ignorant of the precise manner in which it acted, still there is no doubt that the language used by all parties in regard to it could best be explained, by supposing that steam, in some one or more of its manifold ways of operation, was its moving power.

Considering the uselessness of the contrivance of De Caus, and the doubtfulness existing as to that of the Marquis, it is, indeed, only surprising that "the invention of the steam-"engine" should have been attributed to either of them, with such confidence as both French and English writers have alternately shown. So long, however, as the little national rivalry was characterised by a due regard to controversial fairness, there was nothing either unpleasing in its aspect, or likely to prove hurtful in its consequences. But in all such controversies, whether scientific or literary, where either national or personal glory is concerned, the first requisite is that they be conducted with a strict regard to truth and justice; that no false weapons be used, no foul blows dealt, nor unfair advantage taken; and that,—as a natural corollary from such propositions,—where these rules have been infringed, defeat and ignominy deserve to be the result. These remarks may appear severe; but we shall leave our readers to judge, after having perused the following statement, whether they are uncalled for.

In a work entitled 'A Summer amongst the Bocages and 'the Vines,' published in 1840, by Miss Louisa Stuart Costello, a lady favourably known to the world by several of her writings, appears the following letter, which she states, without hinting a suspicion of the truth of the statement, to have been written by Marion de l'Orme, in 1641, to M. de Cinq Mars. Mademoiselle de l'Orme, we need scarcely inform our readers, was a lady whose name only too frequently occurs in the scandalous annals of the Court of Louis XIII.; and Cinq Mars was the hapless d'Effiat, at one time the youthful favourite of that monarch, but also too well known by the recklessness of his life, and the tragic fate which early befell him. There is, we believe, little doubt that between d'Effiat and Marion de l'Orme there were certain passages of love, of which many curious anecdotes have been preserved; and so far there appeared to be some foundation on which the superstructure of the following letter might fairly rest.

"MY DEAR EFFIAT, "Paris, Feb. 1641.

"While you are forgetting me at Narbonne, and "giving yourself up to the pleasures of the Court and the "delight of thwarting M. le Cardinal de Richelieu, I, accord-"ing to your express desire, am doing the honours of Paris "to your English lord, the Marquis of Worcester; and I "carry him about, or, rather, he carries me, from curiosity "to curiosity, choosing always the most grave and serious, "speaking very little, listening with extreme attention, and "fixing on those whom he interrogates two large blue eyes, "which seem to pierce to the very centre of their thoughts. "He is remarkable for never being satisfied with any ex-"planations which are given him; and he never sees things "in the light in which they are shown him: you may judge "of this by a visit we made together to Bicêtre, where he "imagined he had discovered a genius in a madman.

"If this madman had not been actually raving, I verily "believe your Marquis would have entreated his liberty, and "have carried him off to London, in order to hear his extra-"vagances, from morning till night, at his ease. We were "crossing the court of the mad-house, and I, more dead than "alive with fright, kept close to my companion's side, when

" a frightful face appeared behind some immense bars, and a " hoarse voice exclaimed, 'I am not mad! I am not mad! " 'I have made a discovery which would enrich the country " 'that adopted it.' 'What has he discovered?' I asked of " our guide. 'Oh,' he answered, shrugging his shoulders, " 'something trifling enough; you would never guess it; it " 'is the use of the steam of boiling water.' I began to " laugh. 'This man,' continued the keeper, 'is named Salo- " 'mon de Caus; he came from Normandy, four years ago, " 'to present to the King a statement of the wonderful effects " 'that might be produced from his invention. To listen to " 'him, you would imagine that with steam you could navi- " 'gate ships, move carriages, in fact, there is no end to the " 'miracles which, he insists upon it, could be performed. " 'The Cardinal sent the madman away without listening to " 'him. Salomon de Caus, far from being discouraged, fol- " 'lowed the Cardinal wherever he went, with the most " 'determined perseverance; who, tired of finding him for " 'ever in his path, and annoyed to death with his folly, " 'ordered him to be shut up in Bicêtre, where he has now " 'been for three years and a half, and where, as you hear, " 'he calls out to every visitor that he is not mad, but that " 'he has made a valuable discovery. He has even written " 'a book on the subject, which I have here.' *

" Lord Worcester, who had listened to this account with " much interest, after reflecting a time, asked for the book, " of which, after having read several pages, he said, 'This " 'man is not mad. In my country, instead of shutting him " 'up, he would have been rewarded. Take me to him, for " 'I should like to ask him some questions.' He was ac- " cordingly conducted to his cell, but after a time he came " back sad and thoughtful. 'He is, indeed, mad now,' said " he; 'misfortune and captivity have alienated his reason; " 'but it is you who have to answer for his madness: when " 'you cast him into that cell, you confined the greatest " 'genius of the age.' After this we went away, and, since

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* Here Miss Costello, in a note, adds the title of De Caus' book.

"that time, he has done nothing but talk of Salomon "de Caus.

"Adieu, my dear friend and faithful Henry. Make haste "and come back, and pray do not be so happy where you are "as not to keep a little love for me.

"Marion Delorme."

To us, we confess, it always appeared that this letter smacked very strongly of having been concocted in the nineteenth century; and we now beg to inform those of our readers who might at first have been disposed to think differently, that it is, throughout, an attempt at an impudent and fraudulent imposture. So far from "your English lord, the "Marquis of Worcester," having then been in Paris, dangling at the apron-string of "that sweet saint," Mademoiselle de l'Orme, and choosing to appear everywhere in public with so virtuous a young lady, "listening with extreme attention," "fixing on those whom he interrogates two large blue eyes," reading the book of De Caus, of which the keeper of the madhouse so naturally had a copy in readiness for accidental visitors, &c. &c. &c., there was not, and there never had been, at the date of the letter in question, either in France or in England, any such person as a Marquis of Worcester at all, nor was there any such title as that Marquisate in existence! Further, the first peer who bore that title was *not* the Marquis of Worcester of steam-engine fame; and the latter did not become either Earl or Marquis of Worcester for years after the date of the alleged interview with De Caus, from which "he returned" so "sad and thoughtful!"

Henry, fifth Earl of Worcester, was not created a Marqui till 1642, when his son Edward, the author of the 'Centur 'of Inventions,' was known as Lord Herbert. Edward, Lor Herbert, was created Earl of Glamorgan in 1645; and on th death of his father, the first Marquis, who died at the vene rable age of eighty-five years, he succeeded to the Earl dom and Marquisate of Worcester. The second Marqui died, we may add, (although that date is not materi to our present purpose), on the 3rd of April, 1667, and i interred in the cemetery of the Beaufort family in Ragland church.

We are far from accusing Miss Costello of having been a willing accomplice in the literary fraud which we have thus had the satisfaction of exposing as it deserves. That lady will no doubt now regret having been an involuntary instrument in giving currency to the forged document which appears to have been palmed off upon her: for she thereby stamped it with an apparent mark of truth, which, without such authority, it might never have received; but which, for the long space of seventeen years, has enabled it to impose upon various writers in this country, of more or less note, as well as, inferentially, on some at least of their readers. It is only surprising that a lady accustomed, in a considerable degree, to historical research, and herself well skilled in all the more honourable part of the craft of authorship, should have suffered herself to be so grossly deceived; but the lesson will not be lost if it teaches her or others for the future to receive with more caution those fragments of information which, whether on this or on the other side of the Channel, may be too readily offered to their notice. We also think that, after what we have stated, Miss Costello is bound, in self-justification, to make a public statement of the way in which she obtained the fabricated letter, and the grounds on which she relied in believing it to be genuine.

The well-known motto of the Edinburgh Review has been from its commencement, more than half a century ago, "Judex damnatur cum nocens absolvitur;" and in general the writers in it have not been accused either of undue excess of lenity, or of any deficiency of critical acumen. Yet one of their number,* deluded by the Costello fable, talks of "Solomon de Caus, who, as his countrymen say, communicated the discovery of the steam-engine to the Marquis of "Worcester." Hans Christian Andersen, the well-known author of many lively Danish tales, has shared in a like credulity, and says that "Solomon de Caus, the discoverer of "steam, was a remarkable man, far before the age he lived "in, and therefore confined in a madhouse;" * the authority for De Caus' lunacy and imprisonment being just the same as for the Marquis of Worcester having been in Paris, in company with Marion de l'Orme, in February, 1641. The apocryphal legend also figures conspicuously, (without any reference being made to the work of Miss Costello), in no fewer than three successive editions of the 'Life of George Stephenson, Railway Engineer, by Samuel Smiles:'—"Solomon "de Caus," says Mr. Smiles, "who was shut up for his "supposed madness in the Bicêtre at Paris, seems to have "been the first to conceive the idea of employing steam for "moving carriages on land as well as ships at sea. Marion "de l'Orme, in a letter to the Marquis de Cinq-Mars, dated "Paris, February, 1641," &c.; and then follows the greater portion of Miss de l'Orme's precious billet-doux. "It appears," adds Mr. Smiles, "that the Marquis of Worcester "was greatly struck by the appearance of De Caus, and "afterwards studied his book, portions of which he embodied in his 'Century of Inventions.'" This must be all very entertaining to the wicked wag who palmed off on Miss Costello the hoax which has met with such easy victims; but we hope that henceforth the letter in question may no longer be looked upon with so much greater respect than it deserves, as a source of historic truth.

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* Edinburgh Review, No. 171, for January, 1847, Review of Lurine's work 'Les Rues de Paris.'

The few years before and after the middle of the seventeenth century form a most brilliant era in the history of discoveries in natural philosophy; and, quite independent of the hydraulic machine invented by the Marquis of Worcester, some great advances were made at that time, by philosophers whose names have not usually been associated with the steam-engine, towards the right explanation of principles on which its action was at first to depend, as well as towards the construction of the apparatus.

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* 'To Be or Not to Be.' Translated from the Danish by Mrs. Bushby, 1857, p. 187.

Galileo, in 1640-41, surmised the true nature of a vacuum, and of the pressure of the atmosphere. His pupil Torricelli, pursuing the subject after the death of Galileo, invented the barometer, and proved the theory in 1643. Pascal, hearing of it, as he says, at Rouen, published, in 1647, his 'Nouvelles 'Expériences touchant le Vuide,' confirming the deductions of the Italian philosophers; and he caused to be made, in 1648, the memorable experiment of the Puy de Dôme, thereby establishing the variation in the pressure of the atmosphere at different heights, which Descartes had before conjectured:—"Ce qui nous ravit tous," says M. Perier, who, at Pascal's request, made the experiment,—in speaking of the phenomenon observed in it,—"d'admiration et d'étonnement." He further developed the theory, in 1653, by many experiments, which were not published until 1663, a year subsequent to his death, in his 'Traitez de l'Equilibre des Liqueurs et de 'la Pesanteur de la Masse de l'Air.'

Otto de Guericke had in the meantime applied himself to the same subject, and invented an air-pump, the effects of which he exhibited to the assembled German Princes at the Diet of Ratisbon in 1654. An account of this was published by Gaspar Schottus, first in his book 'De Arte Mechanicâ 'Hydraulicopneumaticâ,' in 1657, to which it forms an appendix; and afterwards, with several additions, as Guericke has informed us, in his 'Technica Curiosa,' Norimb. 1664, 4to. Robert Boyle passed some time at Florence in 1642, in which year Galileo died at a neighbouring village; he published, in 1660, 'New Experiments upon the Spring of Air,' and described therein an air-pump he had invented two or three years before, and which had been improved by Hooke. The experiments of the Accademia del Cimento, which are very full upon this subject, were published at Florence in 1666. Otto Guericke did not himself publish until a later period; for although he states in the preface to his work entitled 'Experimenta Nova Magdeburgica de Vacuo Spatio,' that it was completed on the 14th of March, 1663, yet he adds, that, partly in consequence of illness, and partly from other occupations, a delay of seven years occurred in placing it before the world. It was at last published at Amsterdam in 1672; and its appearance then seems to have been in part owing to the exertions of certain illustrious friends of its author. Looking at chapters 27 and 28 of book II., and at the iconismi numbered XIV. and XV., where Guericke describes and delineates a cylinder with a *packed* piston and rod, and states his mode of forming a vacuum, by extracting the air under the piston by means of his air-pump, and thus producing a power for raising weights by the pressure of the atmosphere, we observe a great similarity to the apparatus in which Papin, several years later, when residing at Marburg, formed his vacuum by the condensation of steam. Indeed we think it quite evident that the Marburg Professor not only borrowed the form of the apparatus, but took the novel idea of using the pressure of the atmosphere *as a power*, from the far-famed burgomaster of Magdeburg. Germany thus claims a share in the invention of THE GREAT MACHINE, as it is called, by just anticipation, in the letter to the Marchioness of Worcester from her confessor.

The notion of the existence of such a thing as a vacuum,—which the old doctrine had taught that "Nature abhorred,"—and the right explanation of its true nature; the construction and use of the air-pump; the cylinder with its piston-rod, and piston packed so as to be air-tight although moveable in the cylinder, and with its upper surface exposed, so that the air should act on it as a power, when the close cylinder beneath was exhausted; are all so many distinct steps towards the formation of the atmospheric steam-engine of last century: which, under the hand of Watt, cast off altogether its dependence on the atmosphere, and for the first time became in every sense a true steam-engine; deriving its vacuum from the condensation of steam on one side of the piston, and its power from the impulse of steam on the other, and *vice versâ*, according as the stroke made is downwards, and upwards, in uninterrupted succession.

CHAPTER XI.

DENYS PAPIN — HIS MEMOIR OF 1690 — ATTEMPT TO FORM A VACUUM BY GUNPOWDER — HIS SUBSEQUENT ADOPTION OF SAVERY'S PRINCIPLE — HIS DIGESTER — MISTAKES OF ENGLISH AND OF FRENCH WRITERS IN REGARD TO HIS INVENTIONS — TRANSLATION OF HIS PAPER OF 1690.

WE come now to the Memoir in which Denys, or Dionysius Papin, in the year 1690, availing himself of the apparatus of Guericke, and of the true ideas as to a vacuum and the pressure of the atmosphere, of which we have just been speaking, set forth another important fact which he had observed. This was, that if a close cylinder were filled with steam, and the steam were then allowed to condense, a vacuum would be formed within the cylinder; and that, consequently, a moveable piston, fitted to the interior of the cylinder, would then fall, under the pressure of the atmosphere; just as it did in Otto Guericke's experiment, where the vacuum had been formed by the air-pump.

Papin mentions, in the outset of his Memoir, that he had applied steam to that purpose, in consequence of the failure of a previous attempt he had made to obtain a vacuum by the explosion of gunpowder, in the same cylinder, beneath the piston; the explosion always leaving the vacuum imperfect, on account, as he supposed, of a portion of the air which remained, or, as we should now say, of the gases which were the products of the combustion. But he proposed to carry out his ingenious idea of forming the vacuum by condensation, by the clumsy, tedious, and unprofitable expedient of removing the fire from beneath the cylinder, previous to each stroke or descent of the piston; a method which even the greatest of his admirers among his own countrymen admits was "scarcely tolerable even in an experiment intended to verify the accuracy of a principle;" and which involved so great an expense of time, fuel, and labour, as to make it confessedly of no use in practice.

To practice, accordingly, Papin seems never to have attempted to apply it, notwithstanding the suggestions to that effect contained in his Memoir; and we also find that on the appearance of a better invention for condensing the steam, eight years afterwards, Papin abandoned his own scheme, and betook himself to the construction of an engine, (which, however, turned out not to be a good one), in which he made use of the new plan. As for the applications of a moving-power which he enumerates, and which, if original, would have been ingenious enough, he may have found them, and many more, ready stated to his hand in a book published in London in 1651, entitled, 'Invention of Engines 'of Motion lately brought to perfection; whereby may be 'despatched any work now done in England, or elsewhere, '(especially works that require strength and swiftness), 'either by wind, water, cattel, or men, and that with better 'accommodation and more profit than by any thing hitherto 'known and used.' This is in the form of a letter to Hartlib, author of a celebrated Discourse on Flanders Husbandry, and many other agricultural works. The unknown author of the 'Engines of Motion' says, "I have already erected one "little engine, or great model, at Lambeth." See Stuart's 'Anecdotes of Steam-Engines,' pp. 77-79, where it is suggested that the author may have been the Marquis of Worcester.

The best methods of applying the power to those various mechanical processes, which both Papin and his great advocate M. Arago have treated as difficulties of a very secondary kind, have in reality proved far otherwise; they have exercised the ingenuity of the most eminent engineers for upwards of a century and a half; and without their solution no mechanical power, however great, could be deemed of very much use to the world. The perfection in all kinds of mechanism of which our country now can boast, has not been attained without incessant and most praiseworthy exertion; and it is melancholy to consider how many persons, respectable alike for their talents and character, have sunk under the difficulty of contriving those practical applications which M. Arago, himself always most honourably distinguished in theoretical research, considered as having been made with so much facility. For, alas! "persons "whose whole life has been devoted to speculative labours, "are not aware how great is the distance between a scheme, "apparently the best concerted, and its realisation."

There is no doubt that Papin, who was at one time Secretary to the Royal Society of London, was long best known in England by his *Digester*, described by him in the work mentioned below;* which was published in this country, while most of his other writings, all of them now more or less scarce, were either published abroad, or preserved in the form of memoirs in the Transactions of learned societies. They are therefore inaccessible to most readers, and cannot be continuously examined by any one without very considerable difficulty. The Memoir of 1690, now so much referred to, long lay entombed in the bulky series of the 'Acta Eruditorum Lipsiæ,' and in a small work, a collection of nine of Papin's short treatises, which, although printed in two forms, viz. in Latin at Marburg, and in French at Cassel, both in 1695, is of such singular rarity, that it is even doubtful whether a single copy of it can now be affirmed to be in existence.

It is from these circumstances alone, we firmly believe, and not from any undue national partiality, that the real claims of Papin to some of his ingenious ideas have been so long overlooked; and, from the same cause, we now quite as commonly meet with over-estimates of the degree of credit which really attaches to his experiments, unavailing in practice as many of them may have proved to be.

Not only some English writers, (as has sometimes been erroneously supposed), but some of the principal French authors also, have betrayed an entire want of acquaintance with Papin's Memoir of 1690, and with the ideas suggested in it; and have grounded their estimate of his merit as an inventor either on his well-known '*Digester,*' or on the inferior sort of steam-engine which he described in 1707, or on both of those machines, but on nothing else of a more recondite or remarkable nature. Thus Belidor, in his great and valuable work published in 1739, says, "Pour dire un " mot de l'origine des Machines mûes par l'action du feu, l'on " sçaura que je n'ai trouvé personne qui prit la chose de plus " loin que M. Papin, Docteur en Médecine, Professeur en " Mathématique à Marbourg, et Membre de la Société Royale " de Londres, dans la Préface d'un petit ouvrage, qui a pour " titre: '*Nouvelle manière d'élever l'eau par la force du feu,*' " imprimé à Cassel en 1707,"* &c. M. De Prony, in 1790, after referring to the same work of Papin, says: "Nous ne " parlerons pas de la machine de Papin, qui est plus impar- " faite que celle de Savery; la grande célébrité de ses expé- " riences sur la vapeur est principalement fondée sur l'usage " qu'il en a fait pour dissoudre les os au moyen de son " *digesteur*, très connu sous le nom de *marmite de Papin*,"† &c. &c. And Bossut, in 1796, has followed a similar course; speaking first of the "marmite de Papin," as described in his work of 1682, and then of the publication which appeared, at Cassel, in 1707.‡ While in England, on the other hand, Stuart and Farey, in 1824 and 1827, (not to name other writers), have both done ample justice to all the contrivances of M. Papin that could be cited in connection with the history of the steame-ngine.

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* 'A new Digester or Engine for 'softening bones, containing the de'scription of its make and use in 'these particulars:—viz. Cookery, 'Voyages at sea, Confectionary, Mak'ing of Drinks, Chymistry, and Dy'ing. With an account of the Price 'a good big Engine will cost, and of 'the Profit it will afford. By Denys 'Papin, M.D., Fellow of the Royal 'Society. London, printed for Henry 'Bonwicke at the Red Lyon in St. 'Paul's Churchyard. 1681.' It was printed by an order of the Council of the Royal Society, of 8th December, 1680, (Signed) Chr. Wren.

A Dr. Ducoux, a physician at Blois, who some years ago published a pamphlet on the life and works of Papin,§ dwells on the contents of the latter with what we cannot but term prodigious exaggerations; as, for example, when discussing the subject of steam-boats, he hesitates not to call Papin their "inventor," and to describe the English and American nations as a couple of thieves, who have robbed his country of her glory, and then quarrelled about the spoil! *

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* Belidor, 'Architecture Hydraulique,' tome ii. pp. 308-310.

† De Prony, 'Architecture Hydraulique,' tome i. p. 566.

‡ Bossut, 'Traité d'Hydrodynamique,' tome ii. p. 475, 1796.

§ 'Eloge Historique de Denis Papin de Blois,' &c., par le Dr. Ducoux. Blois, 1838.

Of the ingenuity of Papin's idea of forming a vacuum by the condensation of steam, as well as of the real worthlessness in practice of his contrivance for producing it, we have repeatedly, in former works, expressed our opinion;—an opinion in which we believe every well-informed and impartial mechanician of either country, without exception, will now entirely concur. But it could hardly have been supposed that a French physician would have ventured to utter such gross invectives against other nations, while he was himself in complete ignorance of the most ordinary works of his own countrymen on subjects such as those of which he professes to treat, and had evidently never seen the volumes,—nay, for all that we know to the contrary, had never heard of the names,—of Belidor, of De Prony, or of Bossut.

But perhaps those authors may congratulate themselves on the escape they have made, in *not* having been cited by the learned Doctor; for of those who have in that respect not been so fortunate, we observe that some have been treated with little ceremony. In his pages *Rench* stands for Wren; *Hull* for Hulls; *Edwart* for Edward; *Thurloé* and *Cromwel* for Thurloe and Cromwell. The consonant which he has very unnecessarily abstracted from "*Fitzgeral*," he thrice also, unkindly, denies to "*M. Tregold.*" Mr. Robert Stuart, the nominal author of a 'History of the Steam Engine,' 1824, as well as of the amusing 'Anecdotes of Steam Engines,' 1829, would, we imagine, be puzzled to recognise himself under the title of *Sir Robert Stuart;* still more so under that of *Sir Stuart.* And of the orthography of the name of

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* "Les Anglais et leurs anciens colons se disputaient ainsi nos dépouilles, comme ferait deux larrons qui, après avoir détroussé un voyageur, le laisseraient à l'écart pour se partager son butin."—*Ibid.* p. 61.

"*docteur Hoock*," we cannot say less, than that it is a fair specimen of the accuracy which has superintended the preparation of the *boock* thus set forth by "*docteur Ducoock*."

Dr. Ducoux speaks of the English nation as "nos antago-"nistes d'outre-mer;" an expression which, as he appears to have been a navy and army surgeon, we fear must be held to indicate some rather uncomfortable associations still lurking in his mind. We shall not, however, on this occasion pretend to rival him in his national animosities; nor to depreciate, on account of his trivial indiscretions, the real greatness of his countrymen in science, in arts, and in arms. We rather hail with cordiality the alliance which now unites the two powerful nations whom Nature has made such near neighbours, and who ought to be mutual friends; and we turn with great satisfaction to the work of another French author, which gained a prize proposed by the Imperial Academy of St. Petersburg, and in which it is said (speaking of the same idea of Papin), "Il paroît qu'un de ceux à qui "l'on en doit la première idée est Papin, Médecin François, "Professeur de Physique Expérimentale à Marbourg, et "Membre de la Société Royale de Londres: car outre que "par la fameuse expérience de sa marmite, il a fait connoître "la force de la vapeur, il propose, dans un petit ouvrage "imprimé en 1695, la construction d'une nouvelle pompe "dont les pistons seront mis en mouvement par la vapeur "de l'eau bouillante;" but it is added, with equal justice and modesty, "C'étoit déjà beaucoup que de proposer cette "idée; mais il falloit la réaliser et la mettre en pratique "d'une manière simple et commode. *Les Anglois sont les* "*premiers qui y soient parvenus.*" *

Regarding one of the works of Papin,—viz. his 'Recueil de 'diverses pièces touchant quelques Nouvelles Machines,' to the excessive rarity of which we have already alluded,—Ducoux, writing in 1838, tells the following story:—"Le "seul exemplaire que possédait la Bibliothèque Royale de

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* 'Théorie des Machines mûes 'par la force de la Vapeur de l'Eau. 'Par M. de Maillard, Capitaine-'Lieutenant au Corps Impérial et 'Royal du Génie.' 1784; pp. 8-10.

" Paris, a été tout récemment *soustrait par un lecteur*, que le " bibliothécaire a cru pouvoir me désigner comme *étant " Anglais.* Ce riche cabinet le tenait, je crois, de M. Mo- " lard, membre de l'Académie des Sciences, qui, en 1830, " dans tout Paris, en était le seul possesseur," &c. &c. We can readily pardon our countrymen if they are led, by the mode in which this tale is told, (but which we are far from wishing "pouvoir désigner comme étant *vraiment Français*"), to entertain very considerable doubts as to its accuracy. Possibly the volume in question, like so many more of which the "perte" was long so vehemently,—and, as the event showed, so unjustly,—laid upon the "bibliothécaire" of that great library himself, may ere now have reappeared on its shelves, and be discovered never to have quitted them.* If, however, this hope should unfortunately be disappointed, it is plain that if the "bibliothécaire" was in possession of evidence sufficient to warrant his making such a statement, it was his unquestionable duty to have prosecuted the "soustraiteur" as a thief. If otherwise, every "*lecteur " Anglais*" may thoroughly disregard, as unworthy of further notice, a charge of such a kind, thus vaguely uttered, without any of those specific particulars which would have been requisite in order to establish it, and therefore,—as we think,—to justify its author in making it; and which is, besides, not free from the taint of a suspicion that it may have been dictated by illiberal national aversion.

In his 'Notice Scientifique sur les Machines à Vapeur,' in the 'Annuaire du Bureau des Longitudes' for 1830, M. Arago repeatedly cites and gives extracts from the 'Re- ' cueil;' but he has not mentioned whether the copy with which he was familiar was that stated by Ducoux to have belonged to M. Molard, or whether Paris could then boast of a duplicate. M. Hachette, however, in his 'Histoire des ' Machines à Vapeur, depuis leur origine jusqu'à nos jours,' published in March of the same year in which M. Arago wrote, says, "On ne connoît à Paris qu'un seul exemplaire "de cet ouvrage, qui appartient à M. Molard, membre de "l'Académie des Sciences;" (p. 55, *note*). This circumstance, especially when coupled with Ducoux's story of the subsequent fate of that copy, is certainly a curious verification of the remark which we observe in the 'Acta Eruditorum,' "At cum *opuscula ejusmodi facile deperdi, rariusque de non* "*imprimi soleant;*" and adds force to our repeated request for a complete edition of all Papin's works, prepared by some competent person.

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* See the 'Affaire Libri;' one set of the various pamphlets, &c., published in regard to which, in 1849 and the two succeeding years alone, forms no fewer than twelve thick octavo volumes.

As, however, it appears doubtful whether we can hope ever to see even a single copy of either of the two editions of the 'Recueil,'—of the French one, *i. e.*, of Cassel, or of the Latin one of Marburg, both of 1695,—it is satisfactory to know that contemporary accounts of the contents of that work are preserved in the 'Acta Eruditorum' for 1695, pp. 376-382, and in the 'Philosophical Transactions' for 1697, p. 483. It thence appears that the 'Recueil,' or 'Fasciculus,' was made up of the following separate papers or memoirs:—

1. On the Hessian Pump.

2. On several ways of saving fuel, "chiefly by a contrivance to burn the smoak, by causing a draught of air to "come or be forced down the tunnel of the chimney to the "fireplace."

3. On "several inventions to draw water out of mines by "means of some river not far distant from them, and this is "performed by the pressure of the air to cylindrical vessels, "being alternately evacuated."

4. The paper of 1690, here translated; (see pp. 140-146, *infra.*) "The fourth Letter shows a method of draining "mines where you have not the conveniency of a near river "to play the aforesaid engine," [that, viz., for drawing the water out of mines by means of a neighbouring river, and the pressure of the air on cylindrical vessels alternately evacuated]; "where, having touched upon the inconveniency "of making a vacuum in the cylinder for this purpose with "gunpowder, he proposes the alternately turning a small "surface of water into vapour, by fire applied to the bottom

"of the cylinder that contains it, which vapour forces up the "plug in the cylinder to a considerable height, and which, "(as the vapour condenses, as the water cools when taken "from the fire), descends again by the air's pressure, and is "applied to raise the water out of the mine."

5. Dispute between Mr. Dominique Gulielmini and Mr. Papin concerning running waters.

6. Abridgment of a dispute between himself and the same person concerning the true estimate of powers or moving forces.

7. On instruments proper to preserve flame under water.

8. A description of the diving-bell, or "navis urinatoria," of Prince Charles, Landgrave of Hesse. (This article is mentioned only in the 'Acta Eruditorum,' and omitted in the 'Philosophical Transactions;' from which it may perhaps be concluded that it is contained in the 'Fasciculus' published at Marburg, but not in the 'Recueil' published at Cassel, of which the former is analysed in the 'Acta,' and the latter in the 'Phil. Trans.')

And, lastly, "The whole treatise concludes [with] an "harangue, which the author made when he was admitted "professor of mathematics at Marburgh."

From this analysis it appears tolerably certain, that the work about which so much has been said contained in reality nothing on the subject of steam or a steam-engine, excepting the memoir of 1690, first published in the 'Acta Eruditorum' for that year, and now translated in these pages; and that even the loss of every copy of the 'Recueil,' or 'Fasciculus,' would therefore not have the effect either of invalidating any claims which M. Papin has to be considered an inventor on those subjects, or of diminishing the force of the evidence by which they are supported. He undoubtedly appears to have been a person who displayed very considerable ingenuity on those matters of physical inquiry to which his attention was directed; and if, in the history of the steam-engine, justice was for a time measured out to his name and works with rather a sparing hand, we must confess that in later times that deficiency has been *at least* compensated, by the strenuous, and indeed somewhat exuberant, exertions of his countrymen!

In the meantime, both as an act of justice to the memory of the *ci-devant* Secretary to the Royal Society, and for the convenient reference of our readers, we venture to reprint at full length a translation of the paper published by Papin in the 'Acta Eruditorum Lipsiæ' for 1690, in which we have endeavoured to convey very literally the sense of the original; together with a fac-simile engraving on wood of the figure, with letters of reference, by which the paper in the Leipsig Transactions is accompanied. On this paper, Papin's claims to be considered one of the early inventors of the steam-engine, so eagerly urged by his countrymen, principally depend; and it is, at all events, an interesting record of very considerable ingenuity on his part. Thus all may have it in their power to judge for themselves how far it does or does not justify the somewhat extravagant conclusions which have sometimes been deduced from it.

As some little further contribution towards the project we have commended to the attention of some learned native of the country which claims Papin as a son, we also annex a list of his various works, in so far as known to us.* Without professing to guarantee its absolute completeness, we can at least venture to aver that it is much more perfect than the meagre one furnished by Ducoux; which indeed is deficient in by far the greater number of the items, and erroneous as to some of the rest.

"A NEW METHOD OF OBTAINING VERY GREAT MOVING "POWERS AT SMALL COST. BY DENYS PAPIN.†

"IN the machine for a new use of gunpowder, which is "described in the 'Acta Eruditorum' for the month of September, 1688, the first desideratum was, that the gunpowder "fired in the bottom of the tube A A should fill the whole "cavity with flame, so that the air might be entirely expelled "from it, and the tube remain a perfect vacuum beneath the

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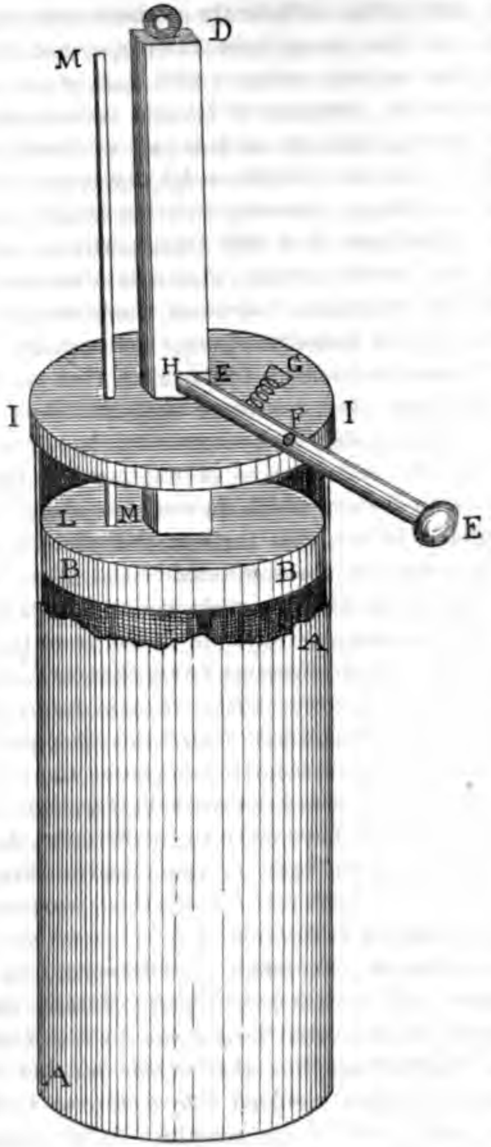
* See Appendix.

† Translated from the 'Acta Eruditorum Lipsiæ' for 1690, pp. 410-414. The paper is also reprinted in the original Latin, in the 'Origin 'and Progress of the Mechanical 'Inventions of James Watt,' 1854, vol. iii. pp. 139-154.

"piston B B. But there it was mentioned, that the desired "effect could not be sufficiently attained; but that, notwithstanding all the precautions there specified, there always "remained in the tube about a fifth part of the air usually "contained in it. Whence a twofold inconvenience arises: "viz. 1st, that in this way we lose half of the desired effect, "so that scarcely can 150 lbs. weight be raised to the height "of one foot, when otherwise 300 lbs. ought to have been "raised, if the tube A A had been perfectly emptied; and "2ndly, that as the piston gradually descends, the force "which makes it descend is itself diminished, as was also "observed in the passage already referred to. Thus we "have to provide, by some contrivance, that, as the moving "force decreases, the resistance may in like manner decrease, so that it may be overcome by the aforesaid moving "force until the end: just as in watches the unequal force "of the main-spring, which moves the whole machine, is "so regulated by art, that through the whole of its running "down it overcomes the resistance of the wheels with equal "ease. But it would be far more convenient if the moving "force were to remain always the same, from the beginning "to the end. Some attempts have, therefore, already been "made to ascertain how a perfect vacuum could be obtained "by the help of gunpowder; for in this way, were there no "air to offer resistance beneath the piston, the whole column "of the atmosphere pressing upon the said piston would press "it with an equable force down to the bottom. But hitherto "such attempts have been in vain; and always, after the "flame of the gunpowder is extinguished, about a fifth part "of the air remains in the tube A A.

"By another way, therefore, I endeavoured to attain the "same end; and, since it is a property of water that a small "quantity of it, converted into steam by the force of heat, "has an elastic force like that of the air, but, when cold "supervenes, is again resolved into water, so that no trace "of the said elastic force remains; I felt confident that "machines might be constructed, wherein water, by means "of no very intense heat, and at small cost, might produce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"that perfect vacuum which had failed to be obtained by "aid of gunpowder. But of the various constructions which "can be contrived for this purpose, the following seemed to "me to be the most suitable.

"A A is a tube of uniform diameter throughout, close shut "at the bottom; B B is a piston fitted to the tube; D D a "handle fixed to the piston; E E an iron rod moveable "round an axis in F; G a spring, pressing the cross rod E E, "so that the said rod must be forced into the groove H as "soon as the piston with the handle has arrived at such a "height as that the said groove H appears above the lid I I; "L is a little hole in the piston, through which the air can "escape from the bottom of the tube A A, when first the "piston is forced into it. The use of this instrument is as "follows:—A small quantity of water is poured into the tube "A A, to the depth of 3 or 4 lines; then the piston is inserted, and forced down to the bottom, till a portion of the "water previously poured in comes through the hole L; then "the said hole is closed by the rod M M. Next the lid I I, "pierced with the apertures requisite for that purpose, is put "on, and a moderate fire being applied, the tube A A soon "grows warm, (being made of thin metal), and the water "within it, being turned into steam, exerts a pressure so "powerful as to overcome the weight of the atmosphere and "force up the piston B B, till the groove H of the handle "D D appears above the lid I I, and the rod E E is forced, "with some noise, into the said groove by the spring G. "Then forthwith the fire is to be removed, and the steam in "the thin metal tube is soon resolved into water, and leaves "the tube entirely void of air. Next, the rod E E being "turned round so far as to come out of the groove H, and "allow the handle D D to descend, the piston B B is forthwith pressed down by the whole weight of the atmosphere, "and causes the intended movement; which is of an energy "great in proportion to the size of the tube. Nor is it to be "doubted that the whole weight of the atmosphere exerts its "force in tubes so constructed; for I have established by "experiment, that a piston, raised to the top of the tube by

" the force of heat, shortly afterwards descends again to the
" bottom, and so on alternately for a number of times, so
" that no suspicion can arise of air pressing beneath. Now
" my tube, the diameter of which does not exceed 2½ inches,
" yet raises sixty lbs. aloft with the same velocity as the
" piston is forced down into the tube, and the tube itself
" scarcely weighs five ounces.

" I therefore have little doubt but that tubes may be manufactured,
" the weight of each of which would scarcely amount
" to 40 lbs., and yet which could raise, at each operation,
" two thousand lbs. to a height of four feet. Moreover, I
" ascertained that one minute's time is sufficient for a moderate
" fire to drive the piston in my tube up to the top; but,
" as the fire ought to be proportionate to the size of the
" tubes, large tubes could be heated almost as soon as small
" ones: whence it is clear what vast moving powers may be
" obtained by help of this most simple contrivance, and at
" how small a cost. For it is known that the column of air
" pressing on a tube whose diameter is a foot, counterbalances
" nearly two thousand lbs.; but if the diameter be two feet,
" the weight would be nearly eight thousand lbs.; and that,
" in other dimensions, the pressure increases in like manner
" in the triplicate ratio of the diameters. Hence it follows,
" that the fire in a grate whose diameter scarcely exceeds
" two feet, might suffice to raise 8000 lbs. each minute to
" a height of 4 feet, if tubes were provided of such a height;
" for a fire might be made in a grate of thin iron, to be
" easily moved from one tube to another, and so the same
" fire might continually be preparing that most efficacious
" vacuum in one tube or another.

" If any one now will consider the magnitude of the forces
" to be obtained in this way, and the trifling expense at
" which a sufficient quantity of fuel can be procured, he will
" certainly admit that this my method is far preferable to the
" use of gunpowder above spoken of, especially as in this way
" a perfect vacuum is obtained, and so the inconveniences
" above recounted are avoided.

" In what manner that power can be applied to draw water

" or ore from mines, to discharge iron bullets to a great distance, to propel ships against the wind, and to a multitude " of other similar purposes, it would be too long here to " detail; but each individual, according to the particular " occasion, must select the construction of machinery appropriate to his purpose. Here, however, I will in passing " remark, how greatly such a power is to be preferred to " common rowers for moving vessels in the sea; for, 1st, the " weight of the common rowers loads the vessel, and retards " its progress; 2ndly, they require much room, and so are a " great hindrance in the ship; 3dly, it is not always possible " to find the requisite number of men; 4thly and lastly, the " rowers, whether they are toiling on the deep, or resting " in harbour, must always be supplied with needful food, " whereby the expenses are greatly increased. But my tubes " would, as has been already observed, have a very small " weight to retard the ship; would also take up little room; " might also be readily prepared in sufficient numbers, if " once a manufactory were built and fitted up for that purpose; and, lastly, no fuel would be consumed for the said " tubes, excepting at the time of the operation; while in " harbour they would require no expenditure.

" But since common oars could not easily be moved by " such tubes, paddle-wheels would have to be employed, such " as I remember having seen in a machine constructed at " London by command of the Most Serene Rupert Prince " Palatine, which was put in motion by horses, by aid of oars " of that sort, and which left a long way behind it the Royal " barge manned by sixteen rowers. So, no doubt, oars fixed " into an axis could be most conveniently driven round by " my tubes, by having the rods of the pistons fitted with " teeth, which would force round small wheels, toothed in " like manner, fastened to the axis of the paddles. It would " only be requisite that three or four tubes should be applied " to the same axis, by which means its motion could be continued without interruption; for, while any one piston might " be touching the bottom of its tube, so that it could drive the " axis round no further, before being again propelled by the

" force of the steam to the top of the tube, the bolt of another
" piston could immediately be removed, the force of which in
" its descent would continue the motion of the axis; and so
" again, yet another piston could be lowered, and exert its
" force on the same axis, while the pistons first pressed down
" were again being raised to the top by the force of heat,
" and so were gaining new force to move the said axis, in the
" manner above described. But one grate, containing a
" moderate fire, would be sufficient to raise all of those
" pistons in succession.

" Perhaps, however, some one may object, that the teeth of
" the piston-rods, fitting into the teeth of the wheels, must in
" their ascent and descent communicate opposite movements
" to my axis; and that so the ascending pistons would hinder
" the movement of the descending ones, and the descending
" pistons would hinder that of the ascending ones. But this
" objection is a very trifling one; for machine-makers are
" well acquainted with a method whereby toothed wheels are
" so fixed to an axis, that when moved round in one direction
" they carry the axis round with them, but when going round
" in the other direction they communicate no movement to the
" same axis, but allow it to be very freely turned round with
" an opposite movement. The principal difficulty, therefore,
" consists in finding the manufactory for easily making very
" large tubes, as I have more fully stated in the *Acta Eru-*
" *ditorum* for September, 1688. And for preparing that, this
" new machine ought to supply no small additional induce-
" ment; inasmuch as it very clearly shows that such very
" large tubes can be most advantageously employed for
" several important purposes."

CHAPTER XII.

THOMAS SAVERY — 'THE MINER'S FRIEND' — DESCRIPTION OF HIS STEAM-ENGINE — USES TO WHICH IT COULD BE APPLIED — PAPIN'S INFERIOR IMITATION OF IT — ESTIMATE BY HORSE-POWER — SIR SAMUEL MORELAND — NEWCOMEN AND CAWLEY — THEIR GREAT IMPROVEMENTS — DESAGULIERS — AMONTONS AND DALESME — SMEATON.

IN the contrivance which has thus made the name of Papin, to say the least, quite as famous as it deserves, the vessel in which the steam was tediously generated, and then allowed slowly to condense, was at once boiler and cylinder; and, so long as it continued to fulfil alternately the functions of both of those vessels, it was necessarily unfit to do any really effective work. In order to the accomplishment of that desideratum, it was essential that the steam should, on the one hand, be steadily, continuously, and abundantly produced, and, on the other, that it should from time to time be condensed with at least tolerable rapidity. The honour of making this great step in advance,—the first that in fact led to the attainment of any really useful results from the employment of steam as a motive power of machinery, and which, therefore, it seems impossible too highly to commend,—belongs entirely to an Englishman, Captain Thomas Savery. Of his life and private history but little appears to be known; and an enquiry made several years ago of a gentleman of the same name at Bristol, (who acknowledged relationship), did not produce any information or papers.

But of his steam-engine Savery has luckily left us a very particular description, in a work entitled 'The Miner's 'Friend, or an Engine to raise Water by Fire described, 'and the Manner of fixing it in Mines, with an Account of 'the several other uses it is applicable unto; and an Answer 'to the objections made against it. By Tho. Savery, Gent. '*Pigri est ingenii contentum esse his quae ab aliis inventa sunt.*

'*Seneca.* London, printed by S. Crouch at the corner of 'Pope's-head Alley in Cornhill. 1702.' The edition from which we copy this title is of that date; but Mr. Robert Stuart, at p. 34 of his 'History of the Steam-engine,' published in 1824, says, quoting from Robison, "The fact is "Savery obtained his patent in 1698, after a hearing of "objections; * * but, besides this, he had erected several "of his engines *before* he obtained his patent;" "and," continues Mr. Stuart, "published an account of his engine in "1696, under the title of *The Miner's Friend,* and *a Dialogue* "by way of answer to the objections which had been made "against it, in 1699; both were printed in one volume in "1702." We have not seen the publication of 1696; but we observe that in that of 1702, he says he worked a small model before some members of the Royal Society, on the 14th of June, 1699; and also, that, previous to the Royal Assent being obtained to the Patent and Act of Parliament, (i. e. in 1698), he had performed an experiment with a small model of the engine before the King at Hampton Court, to his Majesty's "seeming satisfaction of the power and use of it." And he adds, that it is "now fully compleated, and put in "practice in his dominions, with that repeated success and "applause that it is not to be doubted but that it will be of "universal benefit and use to all his Majesty's subjects." What is most important is, that the letter-press of 'The 'Miner's Friend' is accompanied by a very clear and sufficiently well-executed engraving, including two figures, each of about twelve inches in height, of which the first represents "The Engine for raising Water by Fire," and the second represents the same engine "working in a mine." In the former, the various parts are all delineated on such a scale, that, with the aid of the particular description accompanying it, it is impossible to mistake either their proportion or their mode of action; and of both figures it may with perfect confidence be asserted, that they are the first representations to be met with in the publications of any country, *of a real steam-engine doing useful work.*

Savery's engine, as so described and delineated, acted by two distinct principles; raising water, in the first place, by the pressure of the atmosphere forcing it into a vacuum formed by the *condensation of steam;* and, in the second, by *the expansive power of steam.* The steam from the *detached* boiler was let into a vessel called a receiver, and, having driven out the air, was condensed by the affusion of cold water, and a partial vacuum formed. A communication being then opened with a suction pipe, twenty-four feet in height, the lower end of which was placed in a cistern or reservoir of water, that water was forced upwards, by the pressure of the atmosphere, into the receiver. When this was nearly filled, the communication with the suction-pipe was shut off, the steam was re-admitted into the receiver, and by its expansive power forced the water contained in it up an ascending, or, as he called it, a force-pipe. This second operation is similar to one of those experimentally tried by Porta, and indicated by Solomon de Caus; and not only indicated, but perhaps practised, by the Marquis of Worcester. The prior operation,—that of raising the water into a vacuum formed by the condensation of steam,—we believe to have been *original* with Savery. For, although both Porta and Papin had described the principle, they applied it in a different manner; and there is no proof, or even surmise, of its having been known to Savery when he invented his engine in 1696, or perhaps sooner. Indeed, Papin, with praiseworthy candour, as quoted by Belidor, ('Arch. Hyd.,' tome ii. p. 309), writes, "What I say here is not "to give room for believing, that Mr. Savery, who has since "published this invention at London, is not actually the in-"ventor. I do not doubt that the same thought may have "occurred to him, as well as to others, without having learnt "it elsewhere." When we consider the whole of the contrivances invented by Savery, as described by himself in 'The Miner's Friend,' we cannot but accord him the praise of very great ingenuity, independent of the merit of having made THE FIRST WORKING STEAM-ENGINE, (if he was not preceded in that by the Marquis of Worcester); but at all events, of having been the first who introduced it into use. His drawing and description in 'The Miner's Friend,' apply to an engine with two receivers; but it was soon altered, in practice, to one receiver, as we have described it.

Switzer, in his 'System of Hydrostatics and Hydraulics,' published in 1729, says, p. 325, "Among the several engines "which have been contrived for the raising of water for the "supply of houses and gardens, none has been more justly "surprising than that for the raising of water by fire, the particular contrivance and sole invention of a gentleman with "whom I had the honour long since to be well acquainted; "I mean the ingenious Captain Savery, some time since deceased, but then a most noted engineer, and one of the "Commissioners of the sick and wounded.

"It was a considerable time before this curious person, who "has been so great an honour to his country, could, (as he "himself tells us), bring this his design to perfection, on "account of the awkwardness of the workmen who were necessarily to be employed in the affair; but at last he conquered all difficulties, and procured a recommendation of it "from the Royal Society, in Trans. No. 252, and soon after, "a patent from the Crown, for the sole making this engine. "And I have heard him say myself, that the very first time "he played it, was in a potter's house at Lambeth, where, "though it was a small engine, it forced its way through the "roof."

We think it right to add that the language used by Savery in his 'Miner's Friend,' in treating of the advantages, whether ascertained or prospective, of his invention, presents a great contrast, in point of plainness, simplicity, and modesty, to the more high-flown and extravagant phrases in which the Marquis of Worcester so unhesitatingly magnifies the wonderful performance of his "semi-omnipotent" engine. Savery was evidently a practical man, possessed of great common sense as well as ingenuity; and although it would probably be wrong to deny to Lord Worcester the possession of a good deal of the second of those qualities, it may well be doubted how far he is entitled to claim any very considerable share of the first.

Savery, in the second chapter of his 'Miner's Friend,' entitled "Of the uses that this Engine may be applied unto," enumerates—1. The working of mills, by raising water, afterwards to be employed in a steady stream in turning water-wheels; 2. The supplying palaces, or noblemen's and gentlemen's houses, with cisternfulls of water, for domestic use throughout the house, for fountains, or in case of fire; 3. The serving cities and towns with water; 4. The draining of fens and marshes; 5. "I believe," he says, "it may be made very "useful to ships; but I dare not meddle with that matter, "and leave it to the judgment of those who are the best "judges of maritain affairs;" 6. The draining of mines and coal-pits: all of which purposes may, he considers, be answered at far less cost by using his engine than by employing horse-power. And with regard to the last, he suggests that in very deep mines there might be a succession of steam-engines placed at various depths in galleries leading from the shafts.

We have already incidentally referred to Papin having, on the appearance of Savery's invention, abandoned his own idea of 1690, and proceeded to make a steam-engine on other principles, with several variations from that of Savery in the construction of the parts. Belidor, quoting from the work of Papin in 1707, says that "from the year 1698," (the date, it will be observed, at which Savery is said to have obtained his patent, and two years subsequent to the first publication of the description of his engine in the first edition of 'The 'Miner's Friend,' in 1696), "he had made a number of ex-"periments by desire of the Landgrave Charles of Hesse "Cassel, to raise water by fire, which he had communicated "to divers persons, and among others to Leibnitz, who "answered that he also had entertained the same idea.

"This work having been interrupted," continues Papin, "would perhaps have been forgotten, had not Leibnitz, in a "letter of 6th January, 1705, done me the honour to ask my "opinion of the machine of Mr. Thomas Savery, of which he "sent me the print made in London. Although its construc-"tion was a little different from ours, and I had not the "description sent me, I saw at once that the English machine "and that of Cassel were founded upon the same principle,

“ as I showed to the Landgrave; which caused his Highness “ to resume the design of pushing on this invention, which “ without doubt, is a very useful one, as will be seen here- “ after. I can then testify, that it has cost much time, labour “ and expense, to bring it to its present state of perfection. “ It would be tedious to particularise all the unforeseen difficulties met with, and all the trials which have turned out “ contrary to expectation; and, therefore, I shall limit myself “ to making known how far what we now have is preferable “ to what we had done at first, and to what Mr. Savery has “ since done, that the public may not be under any mistake “ in the choice of these different machines, and may profit, “ without trouble, by what has proved so expensive; and “ likewise that they may see that their obligation to his “ Highness is not solely for having formed the first plan, but “ for having overcome the difficulties of the first execution, “ and brought matters to their present state of perfection.”

Belidor, after this long quotation, goes on to observe— “ M. Papin then gives the description of the machine he had “ executed, and forgets nothing to give it value. *But, whatever he may say, it is very far from being equally ingenious* “ *and complete with that of Mr. Savery*, which possesses the “ advantage of having within itself all the movements it “ requires, without any one touching it; whereas the other “ cannot act without the help of several men, one of whom at “ least is required to give his work uninterruptedly, with contrivances *which render this machine as imperfect as that of* “ *Mr. Savery is complete.*” It does not, in fact, appear that the engine improved by Papin, after he was made acquainted with Savery's engine, was ever brought into practical use.

It deserves also to be mentioned that Savery, with the same attention to practical utility by which all of his mechanical proceedings seem to have been characterised, was the first to introduce the idea of horse or horse's power, as the measure of the force of an engine; a term which has since become so familiar as expressing a standard at once convenient in its use, and intelligible to every one. Sir Samuel Moreland had said, in 1683, in speaking of steam when "well governed according to the rules of statics, and "by science reduced to measure, weight, and balance," that "then it bears its burden peaceably, (like good horses), and "thus would be extremely useful to the human race," &c. But that phrase can there be regarded only as a simile used in quite a general sense; while Savery goes on to show that an engine is capable of doing the work not only of as many horses as could at any one time produce an equal effect, but of as many as would have to be kept in order to produce the same effect constantly. "So that an engine," says he, "which "will raise as much water as two horses, working together at "one time in such a work, can do, and for which there must "be constantly kept ten or twelve horses for doing the same, "then I say, such an engine will do the work or labour of "ten or twelve horses." * It is true that the modern use of the same standard has been limited to the lower of those two modes of comparison; but it may be doubted whether the other, employed by Savery, is not in truth the more exact one; as an engine can work day and night without requiring rest, while eight hours, or one-third of that period, are usually considered to be sufficient for a horse to work at one time.

Notwithstanding the importance which we now reasonably attach to the engine thus distinctly put forward by Savery, it met with but little acceptance from the miners to whom he addressed his description and his arguments in favour of its use. Arago says that there was but one exception to their general disregard of the benefits it promised to them; and, as during the term of his patent he does not appear to have made use of any safety-valve, there was evidently considerable danger, with the imperfect workmanship of those days, in using the highly heated steam which he is said to have ventured to employ.

"I have known Captain Savery," says Desaguliers, "at "York Buildings, make steam eight or ten times stronger "than common air; and then its heat was so great, that it "would melt common soft solder; and its strength was so

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* 'Miner's Friend,' p. 29, 1702.

" great as to blow open several of the joints of his machine:
" so that he was forced to be at the pains and charge to have
" all his joints soldered with spelter or hard solder.

" These discouragements," adds Desaguliers, " stopped the
" progress and improvement of this engine, till Mr. New-
" comen, an ironmonger, and John Cawley, a glazier living
" at Dartmouth, brought it to the present form in which it is
" now used, and has been near these thirty years." * (The first edition of Desaguliers' first volume was published in 1734; the first edition of the second volume, from the third edition of which the above passage is taken, was published in 1744.)

Switzer, in his 'System of Hydrostatics,' already quoted, after giving a detailed account of Savery's Engine, says, (p. 335),—" To finish this long account of the surprising Engine
" for the raising Water by Fire, I produce this last improve-
" ment of it by Mr. Thomas Newcomen, which makes it un-
" doubtedly the beautifullest and most useful Engine that
" any age or country ever yet produced." Then, after describing Newcomen's Engine, he says, p. 341,—" What I
" have to add in this place is, that as the best and most use-
" ful improvements which have been discovered either in Art
" or Nature, have, in process of time, been liable to improve-
" ment; so this of the Fire-Engine has been subject to the
" same. For this ingenious gentleman, to whom we owe this
" late invention, has, with a great deal of modesty, but as
" much judgment, given the finishing stroke to it. It is,
" indeed, generally said to be an improvement to Mr.
" Savery's Engine; but, as I am well informed that Mr.
" Newcomen was as early in his invention as Mr. Savery was
" in his, only the latter, being nearer the Court, had obtained
" his Patent before the other knew it, on which account Mr.
" Newcomen was glad to come in as a partner to it."

Newcomen and Cawley became associated with Savery in the Patent obtained in 1705. The engine has, however, always borne the name of Newcomen.

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* 'A Course of Experimental Philosophy,' vol. ii., p. 466, ed. 1763.

The improvements introduced into it were very considerable, compared with the scheme of Papin, or the engine of Savery. In those first made, one cylinder was placed within another, and the interstice was filled with cold water, which effected the condensation with less trouble than the affusion of water, to which Savery had recourse; as he says, "the "water, falling, causes by its coolness the steam, which had "such great force just before, to [lose] its elastick power, to "condence, and become a vacuum, or empty space." * The piston was tightened by packing with leather or rope, and by a stratum of water upon it. A separate boiler was used, as had been done by Savery, for the generation of the steam, and the consumption of water in it was supplied by a pipe from the top of the piston. A snifting-valve was applied for blowing out the air, and an eduction-pipe for getting rid of the water arising from condensation, with improved mechanism of cocks and valves. But the great invention for rendering the power applicable to practical purposes, consisted in a working lever, or great beam moving on a centre, one end being connected with the piston-rod, by means of an arch and chains, and the other with the pump to be worked by it, having a counterpoise for the piston. The subsequent introduction of the cold water into the inside of the cylinder, and the working of the cocks or valves from the great beam, were important points; and, by the last, the steam-engine was rendered a self-acting machine. The details underwent much improvement in the hands of Beighton, and, finally, of the great engineer Smeaton. See the particulars in Farey, ('Treatise on the Steam-Engine,' pp. 138-204). The historical and mechanical information there given, and continued down to p. 308, will be found very deserving of an attentive perusal.

It results from the facts we have adduced, that of the above machine, the first idea of the cylinder, packed piston and rod, and the use of the pressure of the atmosphere as a power, belong to Otto Guericke; the forming a vacuum by

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* 'The Miner's Friend,' p. 19.

the condensation of steam in the cylinder to Papin, who probably was acquainted with the similar experimental process of Porta, conducted, however, with a cistern, instead of the more convenient cylinder; the separate boiler, and perhaps parts of the mechanism of the valves, &c., to Savery. But, whether the ironmonger and the glazier of Dartmouth were acquainted with what Otto and Papin had described in languages probably to them unknown, can only now be guessed at. That they knew something of what Savery had carried into practice six years before is likely, although Switzer appears to consider that they invented the whole. In the history of arts and sciences there have been many cases of apparent coincidence of inventions, of which, the theory of fluxions, bringing into opposition the great names of Newton and Leibnitz, forms the most illustrious instance.

"The way of leathering the piston," says Desaguliers, "was found by accident about 1713; having then screwed a "large broad piece of leather to the piston, which turned up "the sides of the cylinder two or three inches; in working, "it wore through, and cut that piece from the other; which, "falling flat on the piston, wrought with its edge to the "cylinder, and, having been in a long time, was worn very "narrow; which being taken out, they had the happy discovery whereby they found, that a bridle-rein, or even a "soft thick piece of rope or match going round, would make "the piston air and water-tight." [*]

Probably, also, the further packing of the piston by the ingenious method of a stratum of water resting on its plate, was discovered by accident. Its use led directly to a further invention of great importance, and even some elegance:—"One thing is very remarkable; as they at first were "working, they were surprised to see the engine go several "strokes, and very quick together, when after a search they "found a hole in the piston, which let the cold water in to "condense the steam in the inside of the cylinder, whereas "before they had always done it on the outside." [†] And hence followed the substitution of the *rose-head*, to inject a shower of cold water through the interior of the cylinder before each descent of the piston, instead of the application of cold from without; in the first engine in which the injection was introduced into the cylinder, the water appears to have spurted straight up from the end of the injection-pipe. To obtain regularity of the injection, "they used to "work with a buoy in the cylinder inclosed in a pipe, which "buoy rose when the steam was strong, and opened the in-"jection, and made a stroke; thereby they were capable of "only giving six, eight, or ten strokes in a minute, till a boy, "Humphry Potter, who attended the engine, added (what he "called *scoggan*) a catch that the beam always opened, and "then it would go fifteen or sixteen strokes in a minute. "But this being perplexed with catches and strings, Mr. "Henry Beighton, in an engine he had built at Newcastle-"on-Tyne in 1718, took them all away, the beam itself "simply supplying all much better." *

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[*] Desaguliers, vol. ii. p. 533.

[†] Ibid.

Thus, then, by many successive stages had at last been formed a machine in which steam,—to use the figure of speech imputed to Sir Samuel Moreland,—had been reduced to weight, measure, and balance; but which could scarcely yet be said with truth to conduct itself very peaceably, or "like "the best horses," under the various burthens it was intended to bear. For, although it certainly contrived to do a good deal of work, yet it did it in a fashion which was provokingly clumsy, imperfect, and irregular; it would not always move when ordered to do so, nor stop when its progress became dangerous; in the hands of those unaccustomed to attend, to clean, to water, and to exercise it, it would astonish the beholders by snorting wildly, rearing badly, and kicking viciously; it would break even its harness of chains, notwithstanding the "bridles" and "martingales" by which it was curbed; or again, when urged to go at a gallop and exhibit its best racing pace, it would sometimes take a fancy to spite its jockey, move even more sluggishly, work more feebly, and perhaps settle the unprofitable struggle by coming at last to a dead halt.

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* Desaguliers, as above.

"It is now brought to very great perfection," writes Dr. Desaguliers, who would fain have had the credit of improving it beyond all the devices imagined by Lord Worcester, Savery, Newcomen, Cawley, and any others who might have had a hand in the Great Machine; "I shall show," quoth he, "that Captain Savery's method is not unuseful in many "cases, especially when it is changed into the very simple "engine that I have reduced it to, which I shall also de- "scribe." Yet this very perfect and simple engine was apt to have all the faults we have enumerated above: its original cost, also, was not small, and its appetite for fuel was voracious. This last might indeed be called its favourite weakness; for each time that the piston was raised, the cylinder had to be filled with steam, and was therefore heated to an equal degree; while, each time that the steam was condensed in order that the piston might fall, and a stroke be made, the cylinder was cooled down in proportion, and fresh heat, or in other words, more fuel, was wasted in recovering the steam-heat proper for the next rise of the piston. This consideration, although of comparatively small consequence in collieries, "where the power of the fire is made from the refuse "of the coals, which would not otherwise be sold," was practically sufficient to exclude the use of the engine from any application to manufacturing purposes, in localities remote from a cheap supply of coal. Such being the state of the Fire Engine at the middle of the last century, it is not surprising that although many persons had become observant of its performances, few were much enamoured of them; that its real utility was neither very great nor widely extended; that its economy was in most cases questionable; and that numbers of mines and even some collieries were left undrained of the floods which had inundated them, because the proprietors would not risk the doubtful remedy involved in the purchase of one of those machines.

The names of Amontons and Dalesme, which have sometimes been included in the history of the steam-engine at the epoch of Savery and Papin, we need scarcely do more than barely mention. The " Fire-wheel " of the former, of date 1699, of which an elaborate description, with engravings, is given in the 'Mémoires de l'Académie des Sciences' for that year, and also in Leupold's 'Theatrum Machinarum,' 1724, (Tab. 53, fig. 2), consists of a complicated apparatus, depending for its action more on the expansion of heated air than on steam. And of M. Dalesme's project, which bears the date of 1705, the only record that remains appears to be the following, contained in the 'Hist. de l'Académie des Sciences' for that year, and quoted by Prony, ('Arch. Hyd.,' ii. p. 90.) "M. Dalesme laid before the Society some ideas " which it was thought might prove useful, and be deserving " of the outlay requisite for experiments on a large scale. " His notion is, that the force of the steam which rises from " boiling water might be employed as a moving power: he " has shown by a machine in which that force alone made " water spout to a great height, how powerful it is." M. Prony suggests that M. Dalesme's model might still be found to exist in the collection of machines belonging to the Academy; but it never seems to have made its appearance again. The effect described might evidently have been produced by something not more deserving the name of a machine than the hollow ball and tube of De Caus.

The improvements of Smeaton on Newcomen's, or the atmospheric engine, (as it was called from the pressure of the atmosphere on the piston being the moving power in the downward stroke), are the last to which we are here called on to allude before entering on the consideration of those of Watt. In getting engines erected, Smeaton was so much baffled and annoyed by the irregularity and insufficiency of their work, arising often from the bad proportions of their parts, that he constructed a small experimental engine, not above four horses' power, from which he deduced a valuable table of the proportions of the parts and of their relative performance; the experiments are said to have been made about the year 1765, although Smeaton did not proceed to build large engines in accordance with the results obtained, till nine years afterwards; soon after which he designed several, some of them of more than a hundred horse power, and in which it was admitted that there was a considerable saving of fuel,—equal in some cases to one-third of the previous consumption. But those were not in existence at the period of Watt's life to which we must now attend; and even the table we have spoken of was not published by its author, but was found after his death among his papers, now in the possession of the Royal Society.

CHAPTER XIII.

R. ROEBUCK — HIS HISTORY — CARRON IRON-WORKS — BORROWSTONESS — INTRODUCTION TO MR. WATT — PROGRESS OF THE NEW STEAM-ENGINE — TESTUDO BOILER — DIFFICULTIES WITH CYLINDER AND PISTON — PLATE-CONDENSER — CIRCULAR STEAM-ENGINE OR STEAM-WHEEL — DR. ROEBUCK'S EMBARRASSMENTS — MR. WATT'S LAND-SURVEYING AND CIVIL-ENGINEERING — HIS VISIT TO SOHO — INTRODUCTION TO DR. SMALL — RENEWED EXPERIMENTS — PROPOSALS OF PARTNERSHIP WITH MR. BOULTON — PATENT OF 1769.

ROM the narratives of both Dr. Black and Dr. Robison, it s apparent that, next to the inventor himself, the person at rst most deeply interested in the mechanical and commercial ccess of the invention, the origin of which has now been so lly detailed, was Dr. Roebuck; an ingenious and enterprising an, whose ultimate want of success in life ill rewarded his ndness for practical science, and his energetic exercise of ery considerable talents and industry. It seems indeed a ngular fatality, that even his early connection with the reatest invention of his age, full of future profit as it pro-ised to be, and narrowly as we now see that it failed to ealise that hope to him, was not only of no ultimate service o his own fortunes, but had nearly cut short the progress of he invention itself; which was long submerged, and well-igh altogether lost, in the financial wreck in which his ffairs became involved.

For the best account of the life and pursuits of the gentle-an who was thus destined to become the temporary though nsuccessful associate of Mr. Watt in his important scheme, he public are indebted to the pen of the late Professor ardine, of Glasgow College, a person whose memory is eservedly held in veneration by all who in their academical areer enjoyed the advantage of his sagacious, instructive, nd friendly counsels. From a biographical notice which he communicated to the Royal Society of Edinburgh, and which is published in their Transactions,* we find that Dr. Roebuck, who was born at Sheffield in 1718, and received some of his early education under the care of Doddridge and in companionship with Akenside, studied medicine at the University of Edinburgh, and formed there an intimate acquaintance with Hume, Robertson, and others of their eminent contemporaries. Graduating at Leyden, on his return to England he settled as a practising physician at Birmingham, where he rapidly rose into extensive and lucrative employment, and was at the same time enabled to gratify his inquiring habit of mind by numerous scientific researches, in which he engaged with ardour. The study of chemistry, one of his favourite pursuits, he now prosecuted practically, with great ingenuity and perseverance; inventing improved and economical processes for refining and working gold and silver, as well as for manufacturing many other substances commonly used in the arts; and, in conjunction with Mr. Samuel Garbett, establishing a large laboratory, where his various processes were profitably carried out on a very extensive scale. Sulphuric acid, which had previously been made, at great expense, in glass retorts, they succeeded, after many experiments, in preparing, by means of leaden vessels, at less than a fourth of its former cost; and on their establishing a manufactory of it at Preston Pans, in East Lothian, the consumption of the article increased enormously, and the profits of their undertaking became proportionally large.

Emboldened by this success, Dr. Roebuck proceeded to carry out a work of far greater extent and importance, which both in a private and in a national point of view has more than equalled the sanguine expectations then formed of its probable utility. Among the numerous subjects to which he had turned his attention, was the smelting of iron-ore; a process which, as then commonly conducted, was capable, he had satisfied himself, of very great improvement. Having, with his partner Mr. Garbett, now realised some fortune by the profits on his other processes, and being easily enabled, by the confidence reposed in his skill and judgment, to obtain the loan of the further capital that was necessary, he resolved to establish in Scotland a manufactory of iron on a great scale. To him was left not only the direction of all that concerned the buildings, machinery, and processes of the manufacture, but, in the first place, the selection of a proper site for the intended works; and on the banks of the river Carron, in Stirlingshire, he found united every natural facility for his purpose. In that situation, with great water-power, were combined the advantages of ready transport by sea, and supplies, in the immediate neighbourhood, of excellent iron-ore, limestone, and coal,—minerals which, after the lapse of a century, have in that district shown no signs of exhaustion.

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* Trans. R. S. E., iv. p. 65, 1796.

The Carron iron-works, in their original state, were completed by the end of 1759, and the first furnace was blown on the 1st of January, 1760. Dr. Roebuck then lived at the house of Kinneil, near Borrowstoness, a "very ancient and "very stately" mansion,* about three miles from Linlithgow, the rural beauties of which were, half-a-century later, thus described by the poet Campbell, while there on a visit to his venerable friend Dugald Stewart:—"Stewart's residence is "an old chateau of the Dukes of Hamilton, agreeably situated "near the sea, opposite the classic Ben-Ledi, and surrounded "by fine groves that resound with the songs of birds, the "cawing of rooks, and the sweeter cooing of wood-pigeons. "The whole scene, with the society and conversation of my "friends, sinks deep into my mind."†

In planning the Carron machinery, Dr. Roebuck availed himself of the great talents of Mr. Smeaton, who has been justly termed the father of civil-engineering in Great Britain, and who, having in 1750 begun business in London as a philosophical-instrument-maker, was already fast rising to eminence in both of those professions. He had not, however, been previously brought into notice in Scotland; and the introduction of his skill into that country, in which he afterwards directed many important engineering operations, is one of the numerous proofs that Dr. Roebuck gave of possessing an observant and penetrating judgment. Among Mr. Smeaton's Reports, which were published by the Society of Civil Engineers,* and form an interesting memorial of his labours, are included several that were addressed to the Carron Company, concerning the supply and regulation of the water-power, the construction of blowing-machines on improved principles, of mills for boring the great guns known in the British Navy as *carronades*,† and other kindred matters.

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* Sir David Wilkie; see his 'Life' by Allan Cunningham, vol. i., p. 461.

† Beattie's Life of Thomas Campbell, vol. ii. p. 286.

The works established under such advantageous circumstances, and directed by such able advice, did not fail to prosper; and they proved a lucrative investment of the means of their principal projector, as well as of his associated friends. Well had it been for all of them had his attention continued to be engrossed by the profitable manufacture which he had thus so energetically created; but, as the various processes were gradually reduced to little more than mere routine, his ardent mind sought fresh scope for exertion, and he embarked in an adventure, which, although at first it had a semblance of further utility and profit, ended in involving his friends in grievous embarrassment, and himself in irretrievable pecuniary ruin. One of the great principles of the improved method of manufacturing iron, as practised at Carron, was the use of pitcoal instead of charcoal; which, although it had certainly been contemplated and even occasionally attempted in practice in England almost a century and a half earlier,* it remained for Dr. Roebuck successfully to reduce to a general and useful system. An abundant and cheap supply of coal being thus an essential requisite for the continued prosperity of the iron-works, Dr. Roebuck was desirous of securing it by becoming the lessee of the extensive coal-mines belonging to the Duke of Hamilton, at Borrowstoness, where the coal workings were combined with salt-pits. The natural obstacles, however, which presented themselves, (arising chiefly from the great and unexpected depth of the workings), were so formidable as at first greatly to hinder, and ultimately to render hopeless, the success of all his endeavours.

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* In three volumes, quarto, 1812; which were followed, in 1814, by a fourth volume of his Miscellaneous Papers, comprising all of his communications to the Royal Society, printed in the Philosophical Transactions.

† "In the early part of 1779," says Mr. James, in his well-known and admirable 'Naval History,' "a piece of "carriage-ordnance, the invention, by "all accounts, of the late scientific "General Robert Melville, was cast, "for the first time, at the iron-works "of the Carron Company, situated on "the banks of the river Carron, in "Scotland. Although shorter than "the navy 4-pounder, and lighter, by "a trifle, than the navy 12-pounder, "this gun equalled in its cylinder the "8-inch howitzer. Its destructive "effects, when tried against timber, "induced its ingenious inventor to "give it the name of *smasher*." The new gun soon got the name of *carronade*, and those of the larger calibres were found to be so formidable from the force and weight of their shot (from 32 to 68-pounders), that within a very few years of the date of their invention they were introduced into almost every ship in the British navy; while a carronade of smaller calibre (24 down to 12-pounders), was in 1795 ordered to be supplied to the launch of every ship of the size of an 18-gun brig or above it, to aid in the service of cutting out vessels from the enemy's harbours.—See 'The Naval History 'of Great Britain,' by William James, vol. i. pp. 47 and 436, ed. 1826.

It was after he had engaged in that perilous adventure, but before its fatal issue was ascertained, that Dr. Roebuck was brought into connection with Mr. Watt; their mutual introduction having been, doubtless, owing to Dr. Black, with whom Professor Jardine relates Roebuck to have lived till his death in close habits of intimacy, "often acknowledging, "with much frankness, the advantages which he derived in "his various pursuits, from a free and unreserved communi-"cation with that eminent chemist."† From the inventive genius of his new acquaintance, Dr. Roebuck was able to discern that great profit might accrue to the extensive establishments under his own care; his judgment, therefore, no less than his inclination, led him warmly to enter into schemes for rendering effectual in practice the principles which Watt communicated to him; and, an unreserved confidence having been established between them, in the correspondence which ensued are to be found the earliest contemporary records of the progress of the great discovery, which, as we have seen, had "flashed upon the mind" of Mr. Watt in the summer of 1765.

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* See the Account of the "Letters "Patent of Privilege" granted successively to Simon Sturtevant in 1612, John Rovenson in 1613, — Gombleton, Doctor Jordan of Bath, and sundry others, in 'Dud Dudley's Mettallum Martis or Iron made with 'Pit-coale, Sea-coale, &c., and with 'the same Fuell to Melt and Fine 'Imperfect Mettals, and Refine Per-'fect Mettals. London. Printed by 'T. M. for the Authour, 1665;' a curious little book, of which, the original edition having become extremely rare, an exact and careful reprint was published in 1851.

† Biographical Notice, Trans. R. S. E., vol. iv.

"I have tried my new engine with good success," writes Mr. Watt to Dr. Roebuck, 23 Aug. 1765, "for though I "have not been able to get it perfectly air-tight from its bad "materials, yet, immediately on turning the exhausting cock, "the piston, when not loaded, ascended as quick as the blow "of a hammer, and as quick when loaded with 18 lbs. (being "7 lbs. on the inch) as it would have done if it had had an "injection as usual. The moment the steam-cock was opened, "the piston descended with rapidity, snifting all the while, "though the steam was very weak. On the faith of this I "have set about a larger and more perfect model, having "now little doubt of its performing to satisfaction." To Dr. Lind,*—"I have tried my small model of my perfect "engine, which hitherto answers expectation, and gives "great, I may say greatest, hopes of success (for certainty "could not be called hope), in greater model now far ad-"vanced; in short, I expect almost totally to prevent waste "of steam, and consequently bring the machine to its *ulti-"matum*."

On the 9th of September he informed Dr. Roebuck of various experiments and facts, from which he concludes, "That, in proportion as the sensible heat of steam increases, "its latent diminishes, so, in the steam-engine, working with "pressures above 15 lbs. must be more advantageous than "below it; for not only the latent heat is diminished, but "the steam is considerably expanded by the sensible heat, "which is easily added."

On receipt of this letter, Dr. Roebuck expressed his satisfaction at finding that Mr. Watt was so nearly ready to make his trial, and advised him to press it forward with all speed, whether he chose to pursue it as a philosopher or as a man of business. After sending to the Doctor a calculation of an experiment on one of the old engines at Borrowstoness, which, with a boiler 202 feet in area, a cylinder 32 inches in diameter, and of 5½ feet stroke, and 1454 cubic feet of steam produced per minute, made only 11½ strokes per minute, using at each stroke 1454 cubic feet of steam, Mr. Watt wrote on the 11th of October:—“ I have made “ a trial of my machine. It has not entirely answered my “ expectations, though it has no fault but what I think I “ can cure. The principal one, and I believe the only one, “ was the untightness of the piston, which I think I have “ found a remedy for. However, I am certain its consumption of steam will be extremely small, and the condensation “ quick enough; and it may possibly be some days before I “ can come to you, as I must remedy everything before I “ send it away.” And again to Dr. Lind on the 12th of October,—“ I have been making trial of my machine, but “ have not got the piston steam-tight yet; but hope I shall “ accomplish it. My error was applying the ☐ piston to “ it, it being more proper for purposes where the piston is “ drawn against the pressure than for engines where it flies “ from it. I now conceive this to be the best for “ it, as the cloth has a great latitude to adapt “ itself to a bad cylinder, and, if the steam goes “ past one of the rings of cloth, the other will take “ it up. I am at present quite barren on every “ other article, my whole thoughts being bent on this machine; so I can write you nothing else.”

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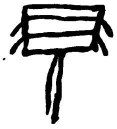
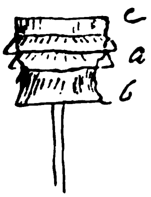
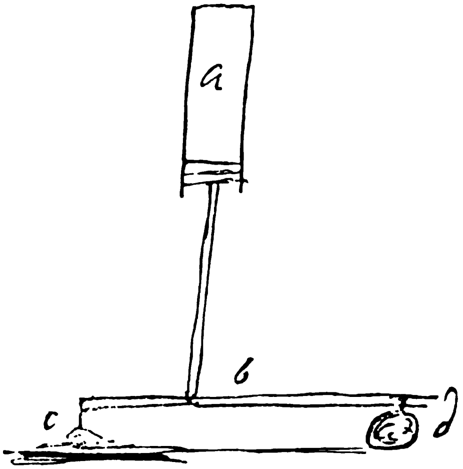
* 4 Sept. 1765.



On the 16th of October, to Dr. Roebuck:—“ On repeated “ trials of my machine I have had better success; it readily “ works with 10½ lbs. on the inch, and sometimes I made it “ lift 14 lbs. I still propose improvements on my piston, “ with which I am confident it will succeed to my utmost “ expectations. This is my present piston. At *a* are two “ collars of varnished cloth; *b* is the old part of the piston, “ which was made for Belidor’s piston, and now remains

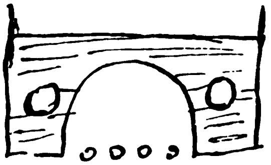




“ naked. I propose adding another collar at *c*, and another “ somewhere on *b*, with which additions I hope “ it will be perfectly tight, as you will easily “ see that the addition of a collar increases “ the tightness vastly. As to the steam con- “ sumed, it is very little; my little boiler fills “ the cylinder in less than half a second after “ it has been exhausted. This is the way in “ which I tried it: *a* being the cylinder, *b* a lever fastened “ down by one end at *c; d* is a weight, which, by being “ moved backwards and forwards, determines the pressure. “ Now, in these circumstances, the weight being in a situa- “ tion where the engine cannot lift it, and vacuum pro- “ duced in *a*, it is plain, on opening the steam-cock, the “ steam will work into *a*, and fill it; to do which, as I said, “ it took less than half a second, which is known by its “ opening the snifting valve so soon as it is *in equilibrio* “ with the air. So soon as the proposed alterations are “ made I shall forward it to you.” And, on 18th October: “ Perfect or imperfect, I will send you the machine next “ week. I find nothing makes it work so well as a strong “ expanded steam.” This was an “ Inverted engine, with a

" new piston, the first not answering. The cylinder of this " engine was five or six inches diameter, with a two-feet " stroke; the inner cylinder was made of copper, not bored " but hammered, and not very true. It was enclosed in a " wooden steam-case, and placed inverted; the piston working through a hole in the bottom of the steam-case. This " was the second of my new engines."

At the same time he describes the performance of a " Testudo" or tortoise-shaped boiler, " the grate formed of hollow tubes, " filled with water," which evaporated 25 lbs. of water with about 4 lbs. of coals in about 44 minutes from the time of boiling; sometimes sooner, but with greater consumption of coals, those used having been very bad; and he speaks of his having another contrivance that would be both less bulky, and more easy of execution.



On 10th November he sends detailed drawings and description for a covered cylinder and a piston, to be cast at the Carron works; whole inside length 7 feet, diameter 24 inches, to be made as truly round and equally wide as possible: which cylinder, however, although afterwards sent to Soho, was never used; having been very ill bored, "though the " best Carron could make at that time."

Before the end of the same year, he had discovered, as he thought, that he could make the piston " extremely air-tight, " and at the same time have little friction," by means of English pasteboard, made of old ropes instead of paper, and oiled; and had also altered the plan of the condenser " from " small pipes to thin interstices between plates: 16 double " plates of a foot square, and half an inch asunder, will " answer the purpose of 900 pipes of an eighth diameter. " This has another advantage, viz. simplicity and greater ease " in making. I have also thought on something new about " the pump of the condenser, and also for the pump in the " pit. Thinking on these things is a kind of relief amidst my " vexations."

This "pipe-condenser" also came to Soho, and many experiments were tried with it; "but it came unsoldered, and the "drum condenser was substituted."

In March and April, 1766, the piston-rod and the new cylinder "for the large machine" were got ready, at Carron; and in the early part of that year occur the first intimations in Mr. Watt's correspondence of "a circular steam-engine" or steam-wheel, the idea of which had occurred to him, and which for a long time continued to divide his attention with the condensing engine. It was an alluring project, because, if successful, it would at once have provided a rotative motion for mill-work, a problem then unsolved by steam; but it took "a great deal more work" than its inventor had imagined; in May, 1766, it was "not yet quite finished, but near it;" and so it remained for years, fresh difficulties arising in its execution as the old ones were overcome, till the patience of most men would have entirely given way.

At this stage of advancement it was,—when the great invention had been visibly and tangibly exemplified in a working model, and while its projector awaited, with eager hope, the performance, on a larger scale, of an engine, most of the parts of which were already constructed,—that the cloud of pecuniary difficulty which overhung the house of Kinneil increased so as grievously to darken all further prospects: discouraging, although not as yet entirely closing, that series of experimental trials which had hitherto been assiduously prosecuted. In September, 1766, Mr. Watt wrote to a friend: "I think I have laid up a stock of experience *that will soon* "*pay me for the trouble it has cost me;*" yet it was between eight and nine years before that invaluable experience was made available so as either to benefit the public, or to repay the inventor; and a much longer period elapsed before it was possible for that repayment to be reckoned in the form of profit. To Mr. Watt, the embarrassments which at so critical a period, and without any fault or even imprudence on his own part, intervened so as to prevent the fulfilment of his designs, were necessarily the source of great disappointment and vexation. But to Dr. Roebuck they were still more disastrous, and never ceased to be matter of the most poignant regret; for, could he have fully anticipated the future development of the invention which now lay before him, he would have seen in it far more than the restoration of all his most prosperous fortunes of past times. And if it be painful in any instance to trace the downward course of an unsuccessful projector, whose want of success has been attendant on abilities and exertions which, under other circumstances, might have ensured a happier fate, most of all must we commiserate the hardship of his destiny when we see, as in this case, that he was tantalised by having the means of recovery within his very grasp, and yet having let them fall from his hand, rendered powerless by the paralysis of poverty.

In the meantime, for some years longer, Roebuck was contending with his adverse fortune, and Watt incubating on such ideas, and, at intervals, practising such experiments, as occurred to him. Both seem,—though, as was natural, in different degrees,—to have continued to entertain tolerably sanguine hopes of the ultimate success of the new "fire-" engine;" but neither of them could make any very decided step in advance, from the want, principally, of those easy circumstances, which, whether of time or of money, were now too commonly denied to both.

The necessities of an increasing family led Mr. Watt, in some measure, to forsake the occupation of a mathematical-instrument-maker, (from which, although the extent of his business had become considerable, the returns were not large), for that of a land-surveyor and civil engineer,—a profession the higher departments of which were then little studied or practised in Scotland. Even in England the labours of Brindley and Smeaton had but recently announced the commencement of a new era in that branch of applied science, while to the north of the Tweed they were only just beginning to be known and appreciated as they deserved. The building of the Eddystone Light-house, perhaps the greatest and most memorable of Smeaton's works, was completed in 1759: and we find that in 1760 he was employed by the magistrates and town-council of Dumfries to report on the best means of preserving and improving the navigation of the river Nith.* "In justice to Father Smeaton," wrote Mr. Watt,† after the lapse of half a century had raised up the gigantic works and established the fame of a Rennie and a Telford, "we should observe that he lived before Rennie, and "before there was one-tenth of the artists there are now. "*Suum cuique*;—his example and precepts made us all "engineers."

In 1767 Mr. Watt was employed, in conjunction with Mr. Robert Mackell, to make a survey for a small canal intended to unite the rivers Forth and Clyde, by a line known as the Loch Lomond passage; which, leaving the Forth some miles above Stirling, was proposed to pass by Bollat into the water of Endrick, and thence by Loch Lomond and the water of Leven, to Dumbarton on the Clyde. But, as it appeared from Mr. Smeaton's estimates and comparison of that line with another which was called the Carron passage, that the former would cost somewhat more, was more circuitous by nearly forty miles, and would have been attended with an additional loss of time in passing between thirty and forty locks, as well as by further expenses in keeping them in repair, the latter was preferred, and an Act obtained for the construction of that useful navigation. Mr. Watt having attended Parliament on the part of the subscribers to the Lomond scheme, appears from some of his letters to Mrs. Watt not to have been much enamoured of that public life of which he thus obtained a glimpse; when "close "confined attending this confounded Committee of Parlia- "ment," he says, "I think I shall not long to have any- "thing to do with the House of Commons again:—I never "saw so many wrong-headed people on all sides gathered "together. As Mac says, I believe *the Deevil* has possession "of them!" ‡

On his journey from London on that occasion, he appears to have made the acquaintance of Dr. Darwin, who writes to him from Lichfield, in August, 1767:—"Now, my dear new "friend, I first hope you are well and less hypochondriacal, "and that Mrs. Watt and your child are well. The plan "of your steam improvements I have religiously kept secret, "but begin myself to see some difficulties in your execution "which did not strike me when you were here. I have got "another and another new hobby-horse since I saw you. "I wish the Lord would send you to pass a week with me, "and Mrs. Watt along with you;—a week, a month, a "year! You promised to send me an instrument to draw "landscapes with. If you ever move your place of residence for any long time from Glasgow, pray acquaint "me. Adieu. Your friend, E. DARWIN." At the same time he first beheld a scene which was soon to become to him one of the most vital interest; for then it was that he first saw Mr. Boulton's great manufactory at Soho near Birmingham; to which he was introduced by Dr. William Small, who, along with Mr. Fothergill, a partner of Mr. Boulton, showed him the works. Mr. Boulton not being at home, those future friends and associates did not at that time meet; but to Mr. Watt's eye, well fitted to appreciate the union of science and art everywhere conspicuous in the various processes which he there witnessed, the manufactory appeared, and with truth, to be a perfect marvel of human ingenuity. "It was the first," says Arago, "which "had been formed on such a large scale in England, and is "still remarked for the elegance of its architecture. There, "Boulton manufactured all sorts of admirable works in steel, "plated goods, silver, and or-moulu; nay, even astronomical "clocks, and paintings on glass. During the last twenty "years of his life, Boulton devoted his attention to improvements in the coining of money. By uniting some processes, "originating in France, with new kinds of presses and an "ingenious application of the steam-engine, he was enabled "to attain at once an excessive rapidity of execution, and "great perfection in the articles produced. It was Boulton "who re-coined, for the English Government, the whole copper "specie of the United Kingdom. The economy and excel-

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* See his Reports, vol. i. p. 1.

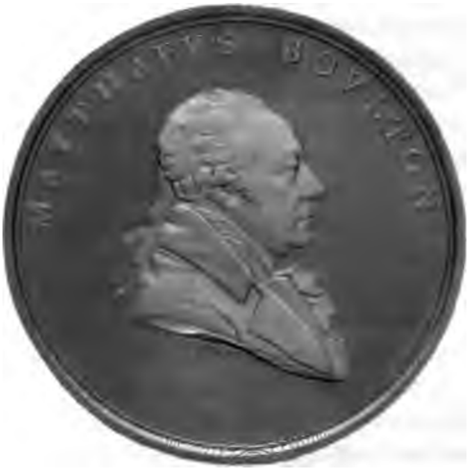
† To Sir Joseph Banks, 18 Aug., 1812.

‡ To Mrs. Watt, London, 5 April, 1767.

"lence with which this great work was accomplished, rendered counterfeits nearly impossible. The executions," [for the crime of false coining], "which in London and Birmingham were every year till then unhappily of frequent occurrence, altogether ceased. It was on occasion of this that "Dr. Darwin exclaimed, in the notes to his 'Botanic Garden,' "'If a civic crown was given in Rome for preserving the "'life of one citizen, Mr. Boulton should be covered with "'garlands of oak!'"

Mr. Boulton also, at a later date, planned and directed the arrangement of the machinery for the British mint on Tower-hill, and executed that for the coining department. He did the same for the great national mints of Petersburg and Copenhagen; as his son afterwards did for the still more extensive and splendid establishments of the East India Company, the Calcutta and Bombay mints. Mr. Boulton struck several fine medals at his mint at Soho, commemorative of persons and events in the late war with France; and, in particular, a beautiful one of Lord Nelson, on the occasion of the victory of Trafalgar, 21st October, 1805; the reverse representing the British fleet bearing down into action in two lines, with the motto, "ENGLAND EXPECTS EVERY MAN "WILL DO HIS DUTY." In a truly patriotic spirit, and with the consent and approbation of Government, he presented one to each officer, sailor, and marine engaged in that memorable action.

Mr. Watt's inspection of the Soho manufactory, and the knowledge he acquired, through Dr. Small's friendly offices, of the talent, enterprise, and success with which that great concern was conducted, seem to have led him greatly to desire that his steam-engine could meet with so happy a fate as to be sheltered and cared for like the other machines which he there saw successfully at work. From the first letter that remains from Dr. Small to Mr. Watt, (of 7 January, 1768), it is evident that some conversation had passed between them on the subject, and that Dr. S., while only informed of the ingenious discoveries recounted to him by Mr. Watt, and as yet ignorant of the precise nature of the



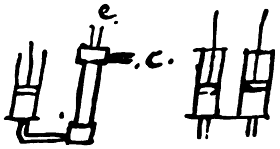
From the Medal by Pidgeon.
Struck at the Soho Mint in [illegible]
Bronze.

connection between him and Roebuck, had formed a great esteem for his new acquaintance, had pressed him to settle at Birmingham, and had engaged, (which in any case he said they would most certainly do), that Mr. Boulton and he should both assist him in every possible way. "I have no "kind of doubt of your success," says Dr. S., "nor of your "acquiring fortune, if you proceed upon a proper plan as to "the manner of doing business, which if you do you will be "sole possessor of the affair, even after your patent has "expired. * * Whether it would be possible to manage "the wheel and reciprocating engines by separate partner-"ships, without their interfering, I am not certain; if it is, "Boulton and I would engage *with you* in either, *provided* "*you will live here.* I am, in haste, dear Watt, your affec-"tionate humble servant, W. SMALL."

They were evidently in greater doubt as to the expediency of forming any intimate business connection with Roebuck, some rumours of the dangerous extent of whose enterprises had probably reached Birmingham; although of him also, it is proper to add, Dr. Small writes, at the same date, "his integrity and generosity, everybody agrees, are "great."

In the earlier part of 1768, Mr. Watt, "close-working," as he terms it, actively renewed his experimental alterations and trials of both the wheel or circulating engine, and the reciprocating or condensing one. Putty and other lutings, intended to keep the complicated valves of the former tight, in reality hindered them from shutting, by being metamorphosed into "the form of little balls;" and contributed to make the completion of that machine,—what it always remained,—a sort of labour of Sisyphus. But in the latter, great progress was made; for, although "the mercury" (with which the piston was packed), "by an unforeseen accident "found its way into the cylinder, and played the devil with "the solder," yet the piston was made to act by steam above it, as well as by the vacuum below it; the cylinder was set wholly in a steam-case; the piston was "extremely tight, and "might easily be made tighter still; made of pasteboard,

" baked with linseed oil, and put on like the leather of a " pump-box." He further proposed making two exhausting barrels instead of one, and giving them each half of its stroke, thereby producing a more perfect vacuum; " making the engine go of itself, " that the strokes may be counted, and the water measured " that is boiled away. These things are in hand, and will " soon be done." This was on the 29th of April, and by the 10th of May he had got the two new exhausting cylinders cast, bored, and partly turned, as well as new condensers made, and expected to have them going again by the end of the week.



" The two cylinders stand side for side; the pipe sat bottom " communicate with two condensers, which, by the pipe *c*, " communicate with the large cylinder. There is a valve at *c* " that prevents the air and water in the condenser from going " into the big cylinder at the return of the piston of the " exhauster, but obliges them to go out at the top of the condenser through the pipe *e*, having a valve at bottom to " prevent their return. This pipe *e* has another use, viz., to " measure accurately the quantity of water condensed [at] " each stroke, by observing what space it occupies in this tube. " I take this to be the best way of determining that article, " if we can make the pistons of the exhausters tight, so that " none may be introduced that way. As soon as I have got " it completed I will write you, that I may either come to " you and give you account of the success, or you come here " and see the machine go. I am uneasy till I know the " exact quantity of steam consumed; though from several " circumstances I think it will answer hopes. At any rate " the vacuum is good and sudden; the consumption undoubtedly the least possible."

After one or two trials which gave good promise, but left " several motions to adjust still," on the 24th of May he was at last able to send the following satisfactory report to Dr. Roebuck:—

"I received yours, and would have answered it sooner if I "could have given you the satisfaction I now can. I this "day had another trial of the engine with the double con- "denser: the vacuum was as before, 14 lbs. on the inch, and "more readily formed, though this new apparatus is not per- "fectly air-tight. From some circumstances it was impossible "to measure the water condensed in the way I proposed, but "I found the engine could easily make twenty strokes per "minute and snift properly, when the steam was middling "strong. I filled the boiler to a certain mark, allowed it to "come a-boil, and boil one hour, in which time it wasted 300 "cubic inches: I repeated this experiment with the same "result nearly. Now 300, divided by 60, gives 5 inches in a "minute, or ¼ inch each stroke. Now, the cylinder is 7½ inch "diameter, squared is 56; deduct ¼ to give square inches: "42 multiplied by 12, the stroke, 504 cubic inches—about "3½-part of a cubic foot; but this used only the ¼ of an inch "of steam. As we could not use all the steam, great part "went off at the loading-valve, and some was needlessly "expended from another cause, which I shall explain at "meeting. Therefore I speak within bounds when I say that "every cubic foot of the contents of the cylinder will require "only one cubic inch of water to be evaporated. I am even "of opinion that, in a large engine, with a strong boiler and "a hot steam, the half of that quantity will be sufficient. "I intend to have the pleasure of seeing you at Kinneil on "Saturday or Friday. I sincerely wish you joy of this suc- "cessful result, and hope it will make you some return for "the obligations I ever will remain under to you."

This result, of which he was too good a mechanician not fully to comprehend the vast importance and great promise in every way, seems quite to have decided Mr. Watt on at all events immediately securing his invention by patent. From a friendly letter full of what was at least meant to be good advice,—a valuable commodity, of which, however, the supply too often exceeds the demand,—written by Professor Jardine to Mr. Watt in 1768, (probably early in the summer), and dated from Kinneil, it is pretty apparent that the inventor had by that time become very doubtful of Dr. Roebuck's ability, under his evident embarrassments, to carry out the invention with the requisite vigour and resources. But, on the other hand, "the more," says Mr. Jardine, "Dr. Roebuck is "convinced of the practicability of the scheme, the keener he "is of carrying it [in]to practice yourselves for your mutual "advantage;" and, while strongly urging him to keep up his spirits and hopes, and recommending him to devote some months to putting up a new engine at Bo'ness, with every aid that the Doctor could furnish, he adds, with characteristic discernment;—"You are surely very near to something that will "be much to your advantage: the happiness, or at least the "interest, of your family,—your own ease and amusement,— "that life of ingenious indolence which you have often figured "out to yourself, are all within prospect;—not to men- "tion the honour of a discovery of so much importance, a "circumstance which few would think so moderately of as "yourself."

Mr. Watt being perfectly satisfied in his own mind of the value of his invention, went to London in August 1768 to make arrangements for taking out a patent for it; only delaying the completion of that step till he should be able, if possible, to secure the aid of a fit associate in the execution of engines for sale, with an equitable adjustment of the chance of profit, or the risk of loss. Mr. Boulton had intended to have met him in town, but being detained at home, invited Mr. Watt to visit him at Soho,—at "l'Hôtel de l'Amitié "sur Handsworth Heath," as he called his own hospitable house,—where he stayed for a fortnight, to the great joy of Dr. Small, Dr. Darwin, and Mr. Keir, who were asked to meet him. Keir, whom Mr. Watt calls "a mighty chemist, "and a very agreeable man," was possessed of considerable literary as well as scientific attainments, and is still known as having been the author of a translation of Macquer's 'Chemistry,' and of an interesting paper on the crystallisation of glass; of another paper in the Philosophical Transactions on the congelation of the vitriolic acid; of a treatise on the different kinds of permanently elastic fluids or gases, in 1777 and 1779; of a fragment of a Dictionary of Chemistry in 1789–90; as well as of an Account of the Life and Writings of the eccentric Philanthropist, Thomas Day, in 1791.

On fully conversing with his guest as to the nature, position, and prospects of his invention, Mr. Boulton expressed a desire to be "concerned in the fire-engine;" but Mr. Watt, with that regard which throughout life he invariably showed not only to the rights and interests but also to the feelings of others, deferred entering into any agreement to that effect until he should first have seen Dr. Roebuck again on the subject, and obtained his full concurrence. This he did on returning to Scotland in October, and the result was thus communicated by him to Mr. Boulton, dated the 20th of that month:—"When you were so kind as to express a desire to "be concerned in my fire-engine, I was sorry I could not "immediately make you an offer. The case is this:—By "several unsuccessful projects and expensive experiments I "had involved myself in a considerable debt before I had "brought the theory of the fire-engine to its present state. "About three years ago, a gentleman who was concerned "with me died. As I had at that time conceived a very "clear idea of my present improvements, and had even made "some trial of them, though not so satisfactory as has been "done since, Dr. Roebuck agreed to take my debts upon "him, and to lay out whatever more money was necessary "either for experiments or securing the invention; for which "cause I made over to him two-thirds of the property of the "invention. The debts and expenses are now about 1200*l.* "I have been since that time employed in constructing "several working fire-engines on the common principles, as "well as in trying experiments to verify the theory. As the "Doctor, from his engagements at Bo'ness, and other business, "cannot pay much attention to the executive part of this, "the greatest part of it must devolve on me, who am, from "my natural inactivity and want of health and resolution, "incapable of it. It gave me great joy when you seemed to "think so favourably of our scheme, as to wish to engage in "it; I therefore made it my business, as soon as I got home, "to wait on the Doctor and propose you as one I wished he "would make an offer to, which he agreed to with a great "deal of pleasure, and will write you in a few days, that if "agreeable you may be a third part concerned, on paying "the half of the cost and whatever you may think the risk "he has run deserves, which last he leaves to yourself. If "you should not choose to engage on these terms, we will "make you an offer when the whole is more perfect, which I "hope it will soon be." * * * "If this reciprocating "engine should not [answer], it must be [from] some mechanical difficulty, which, I think, we may certainly get the "better of. If Dr. Small should choose to be concerned "with you in this, I have reason to think it would be agreeable to Dr. Roebuck, and would be highly so to me. If "you should not choose to engage with this affair in its "present state, or at any rate, you will let this letter remain "a secret except to Dr. Small."

It was in the meantime determined, while awaiting Mr. Boulton's reply, that the patent should be taken out, so as at all events to secure the property in the new engine to its inventor, and those who might be associated with him in its manufacture. On the 5th of January, 1769, accordingly, the memorable patent for "A NEW METHOD OF LESSENING THE "CONSUMPTION OF STEAM AND FUEL IN FIRE-ENGINES" was obtained; and the relative specification in due course, that is, within four months afterwards, enrolled. Dr. Roebuck had agreed, in consideration of receiving an assignation of two-thirds of the property of the invention, to defray the debt (of nearly 1000*l.*) incurred by Mr. Watt in making the previous experiments, and also the expense of the patent, and of any further experiments; while Mr. Watt was "to attend and "conduct the experiments." In reality it turned out that Mr. Watt had to meet all the expenses, with the exception of the debt of 1000*l.*, which Roebuck took, as agreed, upon himself; and although the funds thus required were not of any very large amount, they still were such as Mr. Watt might have had extreme difficulty in providing out of his small profits in the regular way of his business. We have ascertained that, at least to nearly the whole extent required for obtaining the patent, they were advanced by Dr. Black; who in this, as well as in many other ways, had both the ability and the inclination to promote the success of the labours of his young friend.

We need scarcely add that the sum thus provided was gratefully repaid, with interest, by Mr. Watt, when days of greater affluence had dawned upon him. But we feel pleasure in making known this instance, which we believe is not a solitary one, in which Dr. Black showed himself ready to aid a deserving neighbour less opulent than himself; as it has been alleged,—probably not altogether without reason,—that the learned Doctor was somewhat penuriously attached to the saving of money. The considerable fortune which he bequeathed to his relations, (upwards of 20,000*l.*), certainly bore witness to his prudence as a financier no less than to his success as a physician; but on this subject we cannot do better than quote from one of his letters to Mr. Watt, written in the last year of his life,* in which he says,—" You should " study now to enjoy relaxation from business, and the amuse- " ments which are the most suited to your taste; but above " all, relaxation and ease, and gentle exercise, and change of " air. You need not be anxious now about your fortune. It " is already abundant, and it will increase constantly, even " while you are sleeping. It is, however, one of the follies of " old age to be too intent on the accumulation of riches; and " I feel in myself a degree of that inclination. Those of us " especially who have made a little fortune by our own " industry, set a high value on riches on account of the labour " which they have cost us; and when time has put an end to " other enjoyments, one of our greatest pleasures is to increase " the hoard. We do not consider that it is already sufficient " for every reasonable purpose. We have acquired a taste " and a habit which we indulge. If you can be amused with " the works of Horace, you will find in them many pleasant

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* Dr. Black to Mr. Watt, Edinburgh, 1 Feb. 1799.

" allusions to this folly, and ingenious expositions of the " absurdity of it." We can hardly imagine either a more pleasant allusion to the foible in question, or a more sound exposition of the absurdity of it, than those thus delivered by the amiable and philosophic Doctor; whose discourse sounds partly as a warning against the sin, and partly as a rather complacent confession of its commission.

CHAPTER XIV.

SPECIFICATION OF THE PATENT OF 1769—INTERRUPTED NEGOTIATIONS—CONTINUED EXPERIMENTS—EXPANSIVE POWER OF STEAM—SUCCESSFUL TRIAL OF ENGINE AT KINNEIL—PIPE-CONDENSER—FURTHER NEGOTIATIONS WITH SOHO—CONTINGENT AGREEMENT WITH DR. ROEBUCK—POSITION AND CIRCUMSTANCES OF MR. WATT.

WATT, while continuing his experiments at Glasgow, and his preparations for further trials of the engine "in the glen "behind Kinneil," where "the burn afforded plenty of cold "water" for condensation, and there was greater "freedom "from speculation than about Bo'ness," now busied himself in making a draft of the Specification, which had to be given in and enrolled within four calendar months of the date of the Letters Patent. In the preparation of this document, which afterwards became one of great interest in the history of the steam-engine, not only from the nature of its contents, but also from the long and fiercely-contested litigation of which it was the turning point, he received the benefit of the advice of his friends Dr. Small and Mr. Boulton; and the event showed that their enlarged views of the principles on which it ought to be framed, were sound and judicious.

"Mr. Boulton and I," writes Dr. Small to Mr. Watt,* "have considered your paper, and think you should neither "give drawings nor descriptions of any particular machinery, "(if such omissions would be allowed at the office), but "specify in the clearest manner you can that you have discovered some principles, and thought of new applications of "others, by means of both which, joined together, you intend "to construct steam-engines of much greater powers, and "applicable to a much greater number of useful purposes, "than any which hitherto have been constructed; that to

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* 5 Feb. 1769.

" effect each particular purpose, you design to employ particular machinery, every species of which may be ranged in " [one of] two classes: one class for producing reciprocal " motions, and another for producing motions round axes.

" As to your principles, we think they should be enunciated, " (to use a hard word), as generally as possible, to secure you " as effectually against piracy as the nature of your invention " will allow. You might declare in some such manner as the " following:—

" First, you intend that the vessels in which powers of " steam will be employed to work such engines as you may " construct, shall be heated, before the working of the engines " shall begin, at least as hot as the steam to be conveyed into " the vessels, and that this heat of the vessels shall be rendered equable, whilst the engines work, by suffering them " to be entered or touched in that time by no substance " colder than the steam they are designed to receive, by " covering them with materials which allow bodies so covered " to cool very slowly, and by proper applications of heated " bodies when they may be wanted. The vessels mentioned " in this paragraph you call *steam-vessels*.

" Secondly, in the engines which you may erect to be " worked, either wholly or partially, by condensation of steam, " you intend that the steam shall be condensed in vessels " distinct from the steam-vessels, though occasionally communicating with them. These vessels you call condensers; " and, whilst the engine may be working, you intend to keep " the condensers constantly at least as cold as the air then in " the neighbourhood of the engines, by applications of water, " and other means of cooling heated bodies.

" Thirdly, whatever air or other uncondensible elastic " vapour may impede the operations of the engines, you " intend shall be drawn out by machines in the manner of " pumps, to be worked by the engines themselves.

" Fourthly, you intend that on different occasions the " necessary steam shall be produced from different substances, " solid or fluid, or partly solid and partly fluid, as may be " most convenient; and also that the vessels in which the

" steam shall be produced, (which you call boilers), shall be
" of different forms on these different occasions.

"Fifthly, in many cases you design to employ steam in
" producing reciprocal motions in a manner like to that
" in which portions of the atmosphere are now employed in
" ordinary reciprocating engines, to wit, by pressing at proper
" times upon pistons of proper structures.

"Sixthly, to produce by means of steam motions round
" axes, you intend sometimes to employ reciprocatory joined
" to other machines, but more frequently steam-vessels of
" forms fitted to different purposes. These steam-vessels will
" be mounted on axes, and will contain weights, either solid
" or fluid, or partly solid and partly fluid; which weights, or
" the centres of their gravity, being constantly, whilst the
" engines work, pressed by steam beyond planes perpendicular
" to the horizon, and in which planes the axes will
" lie, will cause motions of the steam-vessels.

"Seventhly, in these last-mentioned engines, in which
" steam-vessels must move round axes, on some occasions
" you intend to use the condensers described above; but
" on others, to discharge the steam from the steam-vessels,
" through proper outlets, into the atmosphere.

"Lastly, to render pistons and other parts of the machinery
" air and steam-tight, instead of water you design to employ
" paper and pasteboard prepared with oils, oils themselves, or
" fat of animals, quicksilver, or melted metals."

Dr. Small adds, in a part of his letter written two days later, "I am certain that, from such a specification as I " have written, any skilful mechanic may make your engines, " although it wants correction; and you are certainly not " obliged to teach every blockhead in the nation to construct " masterly engines." The form of specification thus prudently recommended, differed but slightly from that ultimately adopted, which was signed and sealed on the 25th of April, and enrolled on the 29th of that month.

This letter was accompanied by one from Mr. Boulton,* in which he says that Dr. Roebuck had offered him "a share "of his property in the engine, as far as respects the counties "of Warwick, Stafford, and Derby," and then goes on: "I "am obliged to you and him for thinking of me as a partner "in any degree; but the plan proposed to me is so very "different from that which I had conceived at the time I "talked with you upon that subject, that I cannot think it a "proper one for me to meddle with, as I do not intend turning engineer. I was excited by two motives to offer you "my assistance—which were, love of you, and love of a "money-getting, ingenious project. I presumed that your "engine would require money, very accurate workmanship, "and extensive correspondence, to make it turn out to the "best advantage; and that the best means of keeping up "the reputation, and doing the invention justice, would be "to keep the executive part out of the hands of the multitude of empirical engineers, who, from ignorance, want of "experience, and want of necessary convenience, would be "very liable to produce bad and inaccurate workmanship; "all which deficiencies would affect the reputation of the "invention. To remedy which, and to produce the most "profit, my idea was to settle a manufactory near to my "own, by the side of our canal, where I would erect all the "conveniences necessary for the completion of engines, and "from which manufactory we would serve all the world with "engines of all sizes. By these means and your assistance "we could engage and instruct some excellent workmen, who "(with more excellent tools than would be worth any man's "while to procure for one single engine) could execute the "invention 20 per cent. cheaper than it would be otherwise "executed, and with as great a difference of accuracy as "there is between the blacksmith and the mathematical-"instrument-maker. It would not be worth my while to "make for three counties only; but I find it very well worth "my while to make for all the world.

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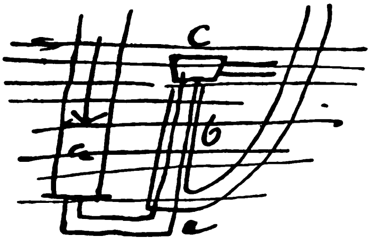
* 7 February, 1769.

"What led me to drop the hint I did to you was the possessing an idea that you wanted a midwife to ease you of "your burthen, and to introduce your brat into the world,

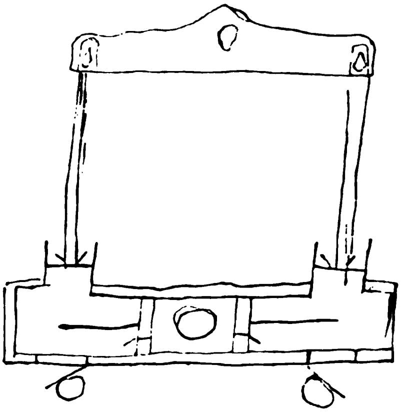
" which I should not have thought of if I had known of your " pre-engagement; but as I am determined never to embark " in any trade that I have not the inspection of myself, and " as my engagements here will not permit me to attend any " business in Scotland, and as the Doctor's engagements in " Scotland will not, I presume, permit his attendance here, " and as I am almost saturated with undertakings, I think I " must conclude to ——. No, you shall draw the conclusion: " yet, nevertheless, let my conclusions be what they will, " nothing will alter my inclinations for being concerned with " you, or for rendering you all the service in my power; and " although there seem to be some obstructions to our partner" ship in the engine trade, yet I live in hopes that you or I " may hit upon some scheme or other that may associate us " in this part of the world, which would render it still more " agreeable to me than it is, by the acquisition of such a " neighbour."

Although the disappointing intelligence of the failure, so far, of the negotiation with Mr. Boulton, reached Mr. Watt just after he had written to Dr. Roebuck that from fresh trials of the engine, " its doing twice as well as the common [one] " is, I think, absolutely certain, from what Mr. Jardine saw, " and there is little reason to fear but what it will do all we " expected," he did not allow it to interfere with the continuance of his experimental improvements. On the 22nd of February he thus describes a further alteration of the condenser, with which he was much pleased :—" In the piston of " the condenser there are valves as in a common pump; it " is 2 inches diameter, stroke " 6 inches; contains 18 cubic " inches water. The pipe *b* " of the condenser is sur" rounded with an outer " pipe; cold water runs be" tween. The pipe *b* and " box *c* contain above 9 " cubic inches water; at *c* is " a sliding valve which is opened, and kept open for a little



" space when the piston *a* is at the lowest. The mouth of
" the pump being above water, the piston, when it was at
" top, threw out almost all the water contained above it;
" when it is at the bottom, the water in the cistern runs in at
" the valve *c* and fills the pump up to the level of the water
" in the cistern, and by that means puts out the water heated
" in the last stroke; when the piston is raised the valve is
" shut, and the steam, or what of it is not condensed, pushes
" the water before it into the pump, and endeavours to follow
" it into the pump, but is condensed with a crack. It is
" not possible, if the water be cold, that any of it can survive
" this operation; and the machine is simple and works easy.
" I propose working the condenser by a waterwheel." On the 14th of March he says:—" I this day made trial of the
" power of the engine, and found that, after it was clear of
" air, it readily lifted 620 lbs., and, I believe, would have
" lifted more, but had none at hand. The whole pressure
" on the piston is about 740 lbs.; this was with a steam not
" able to support above one, or at most two inches of mer-
" cury;"—and, two days after, "Since I wrote you I added
" 80 lbs. to the load of the engine, making in all 704 lbs.
" net, which it lifted easily. However, the additional weight
" being a large mortar and inconvenient, I took it off and
" wrought it a few strokes with the 624 lbs., which it raises
" on half a revolution of the handle of the condenser, or the
" stroke of our pump. This seems to depend wholly on the
" coolness and quantity of water that passes through the con-
" denser, which I have an easy method of increasing. I find
" this cylinder, being of cast-iron, and near one-eighth inch
" wider at one end than it is at the other, is not so steam-
" tight without oil as the block-tin one I had last was; I
" therefore make use of the oil-pump and train-oil, which
" answers perfectly well, keeping a constant circulation. The
" best and cheapest cylinders will be of block-tin; they will
" be defended from external injuries by the wooden case, and
" have nothing to fear from the inside."

Not only was the "tolerably tight piston" here spoken of rather difficult to execute, but the condenser also was constantly undergoing further variations. Its pumps were made "frictionless," but then, they "afforded a lodgment for air;" that plan "was therefore rejected, and block-tin cylinders "put in its place. These cylinders," he says, "are 3½-inch "diameter; the piston moves up and down 1¼ inch; the "piston-stalks are suspended on a beam on edges; the "beam is made to vibrate by means of two spiral wheels that



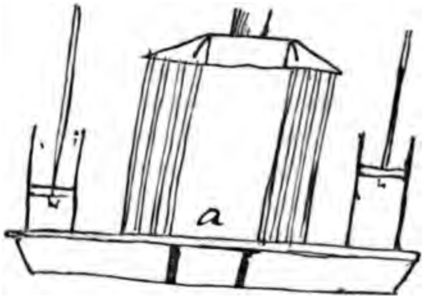
"press down first one end and then the other. This spiral "puts them down very quick in the first part of its motion, "but during the last fourth of its revolution it only moves "them 1¼ inch, that being the only time that anything be-"side friction opposes its motion, as it is then putting out its "water and raising the whole power of the air on the other "piston. During this part of the revolution, the valve at "bottom is opened by a trigger, having little to oppose it, as "that lobe of the condenser is then a plenum; then the "water surrounding the condenser being higher by six inches "than the top of the pumps, rushes up through the con-"denser and pump, and cools it. On trial, the condensation "is more rapid than ever, the force necessary to move the "condenser much less than you could well imagine, and the "ease of execution quadruple what it ever was of any former "condenser, for instance. This one is made of wood and "block-tin."

Then comes a very early intimation of a most important principle, afterwards applied, with the best effect, in the manufacture of the improved engine, and included by Mr. Watt in his patent of 1782; viz. the use of the expansive force of steam as it rushes into a vacuum. Of this, it appears from one of his letters to Mr. Boulton, written in 1781, that he had thought in 1767; but he here most clearly sets it forth, as especially applicable to the wheel or circulating engines, which continued to divide his attention with reciprocating or condensing ones:—"I mentioned to you a method "of still doubling the effect of the steam, and that tolerably "easy, by using the power of steam rushing into a vacuum, "at present lost. This would do a little more than double the "effect, but it would too much enlarge the vessels to use it all; "it is peculiarly applicable to wheel-engines, and may supply "the want of a condenser where force of steam is only used; "for, open one of the steam-valves, and admit steam until "one-fourth of the distance between it and the next valve is "filled with steam; shut the valve, the steam will continue "to expand, and to press round the wheel with a diminishing "power ending in one-fourth of its first exertion. The sum "of this series you will find greater than one-half, though "only one-fourth steam was used. The power will, indeed, "be unequal, but this can be remedied by a fly, or several "other ways."

Gradually the completion of the engine "in great" at Kinneil approached: by 5th July, 1769, almost every part of it was ready for putting together; the boiler was set, the great beam hung; the condenser finished "much to his "liking," with two pumps of tin, 9 inches in diameter, and the rest of it hardened lead, fastened to a strong frame of wood. The iron cylinder, (enclosed in another of wood), the piston-rod, and piston, "the best Carron could produce," were yet "not over good," the cylinder being in one part oval, either from an inaccuracy of the mould in which it had been cast, of the action of the tool by which it had been bored, or from some injury received in setting it up; and the adjusting and fitting together of all the parts occupied a long time.

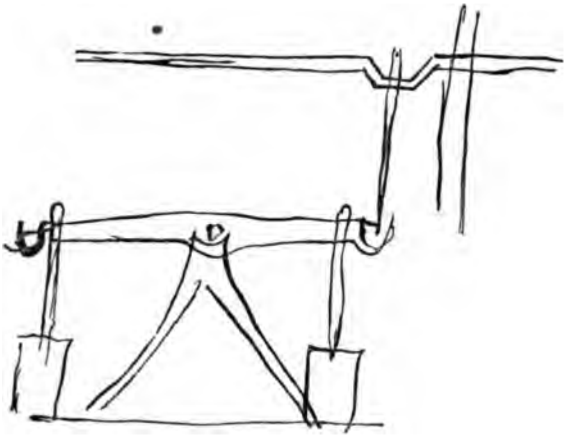
Yet at last, early in September, it was set to work; and, although the first trial did not appear to be decisive either way, chiefly owing to the inequality of the cylinder and consequent untightness of the piston, letting both the steam that drove it and the oil that "packed" it escape, yet Mr. Watt felt that he was still allowed "to flatter himself with " hopes,"—too often now his only indulgence. " The boiler " with a small fire," he says, " easily supplied more steam " than we could destroy, although there were many outlets " for it, which we took no care to stop, being employed " otherwise. The boiler-top and wooden cylinder were very " tight, as were all our vacuum joints and valves; the plates " that let out steam were at the man-hole door and at the " screws that fastened the steam-box to the wooden cylinder, " which, had other things been right, we should soon have " corrected. The only conclusion I can draw from this trial, " is, that supposing we cannot employ oil to keep the piston " tight, and that we cannot make it better than we had it, it " would work easily with 8 lbs. on the inch, and would not " consume above half the steam used by a common engine. " Even this I will not positively affirm, although I think " there is reason to believe it." To correct the elliptical error of the cylinder, he proposed hammering it from the outside on a truly cylindrical block of wood within, and making future cylinders of copper, for the convenience of such adjustments, instead of relying on the bad casting and boring of iron in those days; while soon afterwards he thus describes a new sort of condenser, which he called the pipe-condenser:—" The " new condenser consists of two sets of pipes, eight in each set, " thus:— $\begin{smallmatrix}o\ o\ o\ o & o\ o\ o\ o\\ o\ o\ o\ o & o\ o\ o\ o\end{smallmatrix}$: they are each ¾ inch diameter " and 18 inches long, 16 inches of which will be evacuated " [at] each stroke of the pump; they are to be ½ an inch distant from one another in all directions; each set is to be " surrounded at ½ an inch distant in a box of wood, through " which cold water can be made to run at pleasure. They " are joined at top by a thin cast-iron box, through which " they communicate with the steam. It is made sloping at

" the ends, that as little useless water as possible may be in " circulation. They are joined at bottom by another cast-



" iron box, through which they communicate with the pumps, " which are of copper, 5 inches diameter; two diaphragms of " wood prevent their communicating with one another, the " box being continued only for strength. It was indeed ori- " ginally made with an intention to have no communication " at top, but the steam to enter at *a*, by which means the " valves needed only be water-tight, whereas they must be " air-tight above; but on condensation the steam, whenever " it entered, (which would be as soon as any part of the pipes " was empty), would rise, or attempt to rise, through the " water in the pipes, and would heat it; but the piston of " the pump still ascending, that water would descend into the " box below, and part might get into the pump, and be there " converted into steam; not being exposed to much conden- " sation at best, if it got no further than the box it would re- " main warm until the cold of the pipes made a vacuum, " when it would boil and go to them to be condensed, and it " is much to be feared that this heating and cooling might " prolong the time of condensation. I have sometimes " thought that something of this kind happened in the other " condenser, and concurred with other devils to plague me; " and indeed I was so out of humour with myself and it, I did " not try all experiments I might have done to clear that up. " I make use of the same beam and crank I had before, only " I place these pumps at the extremities of the beam, where " they have about four inches stroke. The way the crank is

" applied I think simple, yet answers as well as a crank can " answer."



After the experiment at Kinneil had afresh inspired him with at least partial confidence, which, however, he always is careful to express with great modesty, Mr. Watt pressed Dr. Roebuck, who was then about to set out on a journey into England, to try to conclude some bargain with Mr. Boulton; " which," he says, " even though it should appear a little " hard for us, I would wish you to accept, from the following " considerations:—1st. From Mr. Boulton's own character as " an ingenious, honest, and rich man. You know him much " better than I do, but the worst I have ever heard of him " amounted to his being a projector. 2ndly. From the difficulty and expense there would be of procuring accurate " and honest workmen, and providing them in proper utensils, " and getting a proper overseer or overseers. If, to avoid " this inconvenience, you were to contract for the work to be " done by a master-workman, you must give up a great share " of the profit. 3rdly. The success of the engine is yet far " from being verified. If Mr. Boulton takes his chance of " success from the account I shall write Dr. Small, and pays " you any adequate share of the money laid out, it lessens " your risk, and in a greater proportion than I think it will " lessen your profits. 4thly. The assistance of Mr. Boulton's "and Dr. Small's ingenuity (if the latter engage in it) in "improving and perfecting the machine may be very considerable, and may enable us to get the better of difficulties "that might otherwise damn it. Lastly. Consider my uncertain health, my irresolute and inactive disposition, my inability to bargain and struggle for my own with mankind; "all which disqualify me for any great undertaking. On "our side, consider the first outlay and interest; the patent; "the present engine, about 200*l.* (though there would not be "much loss in making it into a common engine); two years "of my time, and the expense of models."

While thus, on the one part, it had come to be a question with the inventor, whether there would be "much loss" in converting the machine which was to revolutionise the whole face of the habitable globe, "into a common engine," on the other, both Mr. Boulton and Dr. Small had in the meantime engaged most of their money in other affairs:—"I am really sorry," quietly writes Mr. W. to the latter, "on my own account, that your engagements hinder you from "entering into our scheme; for that ought to be the result of "your deliberation. Though there are few things I have "wished more for than being connected with you, on many "accounts, yet I should be very loth to purchase that pleasure at expense of your quiet, which might be the case "if you involved yourself in more business than you could "easily manage, or, what is worse, find money for. Besides, "this is not a trade, but a project. No man should risk "more money on a project than he can afford to lose. I "must, however, beg the favour of writing to you as though "you were concerned." *

And Dr. Small, not outdone in either generosity or true friendliness, at once replies: †—"Nothing will give me more "pleasure than to contribute in any degree to your prosperity, whether I can become an associate with you or not. "Although I hate debts, yet on this occasion I have ventured "to propose borrowing money from the only persons to whom

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* October 21, 1769.

† 5 November, 1769.

" I would be obliged in that manner. Should it suit them to " accommodate me, I will accept Dr. R.'s offer immediately, " as will our friend Boulton."

And again; — " I had your letter three days ago, and " have held several conversations with our friend Dr. Roe- " buck about the scheme. He goes to London to-morrow, to " stay one week, and in that time Boulton and I shall deter- " mine whether we can accept the offer he has been so " obliging as to make us. Unluckily we have both just " engaged in another scheme, which will very speedily require " all the ready money we can at present spare, and I have a " vast aversion to borrowing, although I would sooner borrow " on this occasion than on any other I know, both because " the engine must succeed, and because it is your affair. * * " Your detail about the engine I have considered very care- " fully, and am in no degree discouraged. * * Boulton " and I will do anything we can do to have you here, and to " forward your success. Dr. R.'s proposal is perfectly agree- " able to us; only as to me it is unfortunately made after the " engagement of very near all my money. You shall hear " from us again in less than a fortnight. In the mean time " favour me with a few lines. All your friends here think of " you with the highest esteem." *

The following was Dr. Roebuck's very moderate, and, indeed, liberal offer, referred to by Dr. Small; dated Birmingham, Nov. 28, 1769, and addressed "To Dr. Small and " Mr. Boulton."

" Gentlemen,—Whereas Mr. James Watt has assigned to " me two-thirds of the property of the patent of the steam- " engine, which he took out some time in the course of the " last winter, I hereby offer you one-half of the above two- " thirds, or one-third of the whole patent, on condition that " you pay to me such a sum, not less than one thousand " pounds, as you, after the experiments of the engine shall " be completed, shall think just and reasonable; and twelve " months from this date you are to take your final resolution.

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* 10 October, 1769.

" I also oblige myself to procure Mr. Watt's assent to this " agreement. I am, Gentlemen, your obedient servant, John " Roebuck."

It at once attained a ready assent:—" I have time only to " say," writes Dr. Small to Mr. Watt, " that Mr. Boulton and " I have agreed with Dr. Roebuck;"—whereupon Mr. Watt replies, " I received yours, and shake hands with you and " Mr. Boulton on our new connection, which, I hope, will " prove agreeable to us all."

The " final resolution " mentioned in Dr. Roebuck's proposal as to be taken at the expiration of one year, does not appear to have been then insisted on by any of the parties concerned in it; but soon after that time, great commercial embarrassment began to spread over Great Britain, and the poor Doctor's already wavering fortunes, unable to stand any fresh assault, fell in the general crash. This event might indeed have hastened rather than further retarded a definitive arrangement as to the steam-engine patent, and an attempt at its manufacture, but for the highly honourable and delicate feelings by which, it became very evident, all were alike influenced. " You are sensible," writes Dr. Small,* " that both Boulton and I engaged in the patent scheme much " more from inclination to be in some degree useful to you " than from any other principle, so that, if you are prosperous " and happy, we do not care whether you find the scheme " worth prosecuting or not." " I do fear," writes Mr. Watt,† " that in this affair I may have urged you too far and with " too little delicacy; and that you have some reason from " them to think more meanly of me than I deserve. I " assure you, whatever I have said as to price, &c., I only " meant in respect to my friend the Doctor, who I am of " opinion ought not at present to risk anything of conse- " quence, and has too much at stake in the matter. As to " myself, I have never thought of receiving money for any " part of my own property in it, and shall perhaps be willing " to hold a much smaller share in it than you would ask me.

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* 17 September, 1770.

† To Dr. Small, August, 1772.

" Although I am out of pocket a much greater sum upon " these experiments than my proportion of the property of " the engine, I do not look upon that money as the price of " my share, but as money spent upon my education. I thank " God that I have now reason to believe that I can never " while I have health be at any loss to pay what I owe, and " to live at least in a decent manner. More I do not violently " desire."

And again,*—" I pursued my experiments till I found that " the expense and loss of time lying wholly upon me, through " the distress of Dr. Roebuck's situation, turned out to be a " burthen greater than I could support; and not having conquered all the difficulties that lay in the way of the execution, I was obliged for a time to abandon the project. " Since that time I have been able to extricate myself from " some part of my private debts, but am by no means yet in " a situation to be the principal in so considerable an undertaking. The Doctor's affairs being yet far from being reinstated give me little hope of help from that quarter; in the " meantime, the time of the patent is running on. It is a " matter of great vexation to me that the Doctor should be " out so great a sum upon this affair, while he has otherwise " such pressing occasion for the money. I find myself unable " to give him such help as his situation requires; and what " little I can do for him is purchased by denying myself the " conveniences of life my station requires, or by remaining in " debt where it galls me to the bone to owe.

" Notwithstanding my natural despondence, I am convinced " that the machine may be made to answer in a very considerable degree, and in more forms than one, but that " I am by no means a proper person to carry it into execution.

" The Doctor is on the contrary too sanguine, and always " thinks things easier than they are. His present exigencies " may also tempt him to insist upon higher terms for his

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* To the same, 30 August, 1772.

" property in it than it is really worth. But I expect, if you " still think it worth while to engage in it, that you will both " give him what you judge the value of it to you, and be at " some pains to convince him of its being his interest to " accept of it. I shall be content to hold a very small share " in it, or none at all, provided I am to be freed from my " pecuniary obligations to him, and have any kind of recom- " pense for even a part of the anxiety and ruin it has involved " me in."

* * "As to the engine, I am not afraid of being able to " carry it on with a small capital, or almost none, provided " the success was certain, or that I was in such circumstances " as to be able to make the necessary experiments for esta- " blishing its merit. I have often mentioned to you that " nothing gave me so much pain as the having involved Dr. " Roebuck so deeply in that concern; and when I wrote you " last, I would willingly have given up all prospect of profit " to myself from it, provided he could have been indemnified. " He is now willing to part either with the whole, or the " greatest part of his property in it, upon such terms as, I " dare say, in better times you and Mr. B. would have had " no hesitation of accepting. Since Dr. R. saw you he is " totally disappointed of the lease of the colliery at Wemyss, " and was here lately in lower spirits than I ever saw him. " His enterprising mind being by that means turned off from " the coal schemes, his Bo-ness affairs going on badly, and he " having no voice in the management of them, he had turned " his thoughts towards the engine, and flattered himself he " could finish the experiment on a small engine, not recol- " lecting that I had been sufficiently successful with an engine " of that size formerly, and that it was only in the 18-inch " engine that the difficulties appeared. I have, however, " dissuaded him from it, as, without flattering myself, I cannot " imagine that he can find out in a few days all the difficul- " ties, and the means of avoiding them, which have cost me " so much labour. I had also two other reasons against it, " the exposing the contrivance to ignorant strangers, and that " he could not go on with it without directions, plans, and

" visits from me, which in my present situation I cannot " make.

" I talk of interesting you more in the success, because " generosity *ought* to go a small way in directing our actions, " and you have hitherto had little other motive excepting a " promise of being concerned if we could agree upon terms. " We may disagree about terms; we may from caprice or " interest break that promise; or we may suddenly be called " by death to another state, and our heirs may laugh at any " promise that is not written upon stamped paper. Consider " what I have said. Consider also that Dr. R. owes Mr. " Boulton money, which will go in part of the price, which " can never be so low as at present. I am sorry that there " is occasion to ask a price, but it cannot be helped; the " Doctor's circumstances oblige him to demand it if he parts " with any great part of the property.

" I by no means intend to insinuate by this that I consider " it necessary that you should pay down a sum of money " before we would assign to you *any* part of the property; " on the contrary, I think that you and Mr. B. ought to " have a *certain* share without advancing to the Doctor " or me, provided you took upon you the charge of the " future experiments, and of finding money to carry on " the business in case of success. What that share should " be must be the result of some conversation between " us. But I would much rather have the matter so settled " that *at least* the half of the property should belong to " Mr. B. and you. At any rate let us be on such a footing, that the experiments may go on, and the matter be " concluded." *

There can be no doubt that even this contingent transfer of one-third of the property of the patent to his two friends was of some comfort to the now drooping spirits of the poor inventor; he much liked Boulton and Small, he valued their personal attachment, admired their mechanical ingenuity, and clear-sighted yet liberal business views and habits, and it was pleasant to him to be concerned with them even without much hope of immediately increasing his own fortune. Such hope, indeed, began to appear even more distant than ever; for it was now more than four years since "the capital "improvement" had "flashed upon his mind, and filled it "with rapture;" yet still, though fortified with a patent, and satisfied of the value of his invention, could it only be duly exemplified and carried out, he found himself left without any profitable return, and even involved in some debt. This was not yet, it is true, of any large amount, but still sufficient to begin to throw a lengthening shadow in the sunshine of his life; for "it cut him to the bone to owe." His family, also, had increased, and he had now attained to the onerous dignity of being the father of three children; but, unhappily, without receiving that triple proportion of corn, which, among the Romans, the "jus trium liberorum" brought with it. Those little voices, "whose crying was a cry for gold," were not to be stilled by the baser metal of a badly cast Carron cylinder, or the "block-tin and hammered lead" of a Glasgow condenser. So that we cannot wonder to find him writing, as he did some time before the acceptance of Roebuck's proposal,—"I am resolved, unless those things I have brought to some "perfection reward me for the time and money I have lost "on them, if I can resist it, to invent no more. Indeed, I "am not near so capable as I was once. I find that I am "not the same person I was four years ago, when I invented "the fire-engine, and foresaw, even before I made a model, "almost every circumstance that has since occurred. I was "at that time spurred on by the alluring hope of placing "myself above want, without being obliged to have much "dealing with mankind, to whom I have always been a dupe. "The necessary experience in great was wanting; in acquiring "it I have met with many disappointments. I must have "sunk under the burthen of them if I had not been supported by the friendship of Dr. Roebuck. * * I have "now brought the engine near a conclusion, yet I am not in "idea nearer that rest I wish for than I was four years ago. "However, I am resolved to do all I can to carry on this

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* To Dr. Small, 7 November, 1772.

" business, and if it does not thrive with me, I will lay aside
" the burthen I cannot carry."

And again, in March, 1770;—" It is a damned thing for a
" man to have his all hanging by a single string. If I had
" wherewithal to pay the loss, I don't think I should so much
" fear a failure, but I cannot bear the thought of other people
" becoming losers by my schemes, and I have the happy disposition
" of always painting the worst."

CHAPTER XV.

MR. WATT'S CIVIL-ENGINEERING — CONSTRUCTION OF THE MONKLAND CANAL — STEAM-BOATS FOR CANALS — SCREW-PROPELLER OR SPIRAL OAR, 1770 — SURVEY FOR CANAL IN STRATHMORE — HAMILTON BRIDGE — CHANNEL OF THE CLYDE — CRINAN CANAL, AND OTHER WORKS — SURVEY FOR CALEDONIAN CANAL — TELFORD — RATE OF REMUNERATION OF ENGINEERS IN THE LAST CENTURY.

In this state of matters, every employment that enabled Mr. Watt to earn an independent income, and served to relieve his mind, now too constantly occupied with anxious and uncomfortable thoughts, was doubly welcome; and he was gradually led more frequently to forsake the solitary vigils of his workshop in the city, for the active labours of his profession of a civil engineer. "Somehow or other," as he modestly expresses it,—or, as we cannot doubt, from his ability and integrity having now become well known,—the magistrates of Glasgow had for two or three years past employed him in various engineering works of importance. In 1769 he made a survey and estimate for a navigable canal from the collieries at Monkland in Lanarkshire to the city of Glasgow; which was carried out under his own directions and superintendence, to the great advantage of the public as well as of the parties to the undertaking.

"I somehow or other," he says,* "got into the good graces "of our present magistracy, who have employed me in "engineering for them (as Mr. Smeaton terms it); among "other things I have projected a canal to bring coals to the "town;—for though coal is everywhere hereabout in plenty, "and the very town stands upon it, yet measures have been "taken by industrious people to monopolize it and raise its "price 50 per cent. within these ten years. Now this canal

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* To Dr. Small, 12 December, 1769.

" is nine miles long, goes to a country full of level free coals " of good quality, in the hands of many proprietors, who sell " them at present at 6*d.* per cart of 7 cwt. at the pit. There " is a valley from Glasgow to the place, but it has a rise of " 266 feet perpendicular above our river; I therefore set that " aside, and have found among the hills a passage, whereby a " canal may come within a mile of the town without locks, " from whence the coals can be brought on a waggon-way. " This canal will cost 10,000*l.*—is proposed 16 feet wide at " bottom, the boats 9 feet wide and 50 feet long, to draw " 2½ feet water."

" Vanity also," he adds,[*] " bade me tell Glasgow people " they might be served as well at home as by strangers. The " time has not been thrown away, for the *vaguing*[†] about " the country, and bodily fatigue, have given me health and " spirits beyond what I commonly enjoy at this dreary season, " *though they would still thole amends.* Hire yourself to some- " body for a ploughman; it will cure ennui."

And, although " a determination that everything should " yield to the engine," led him to refuse going to London with the Bill for the Monkland Canal, yet, after the Act for it had been obtained, and he was again asked to superintend the execution of the canal, he felt himself obliged not to refuse that request. " I had now a choice," he says,[‡] " whether to go on with the experiments on the engine, the " event of which was uncertain, or to embrace an honourable " and perhaps profitable employment, attended with less risk " of want of success:—to carry into execution a canal pro- " jected by myself with much trouble, or to leave it to some " other person that might not have entered into my views, " and might have had an interest to expose my errors; (for " everybody commits them in those cases.)

" Many people here had conceived a much higher idea of " my abilities than they merit;—they had resolved to encou- " rage a man that lived among them rather than a stranger.

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[*] To the same, 3 January, 1770.

[†] " *Vagor* expeditus."—HOR.

[‡] To Dr. Small, 9 September, 1770.

"If I refused this offer I had little reason to expect such a
"continuance of favourable circumstances soon. Besides, I
"have a wife and children, and saw myself growing grey
"without having any settled way of providing for them.
"There were also other circumstances that moved me not
"less powerfully to accept the offer: which I did: though at
"the same time I resolved not to drop the engine, but to
"prosecute it the first time I could spare.

"Nothing is more contrary to my disposition than bustling
"and bargaining with mankind:—yet that is the life I now
"constantly lead. Use and exercise render it rather more
"tolerable than it was at first, but it is still disagreeable.
"I am also in a constant fear that my want of experience
"may betray me into some scrape, or that I shall be imposed
"upon by the workmen, both which I take all the care my
"nature allows of to prevent. I have been tolerably lucky
"yet: I have cut some more than a mile of the canal, besides
"a most complicated gash in a hill and made a bridge and
"some tunnels, for all which I think I am within the esti-
"mate, notwithstanding the soil has been of the very hardest,
"being a black or red clay engrained with stones. We are
"out altogether 450l.—of which about 50l. for utensils: our
"canal is four feet water and sixteen feet bottom. I have
"for managing the canal 200l. per annum; I bestow upon it
"generally about three or four days in the week, during which
"time I am commonly very busy, as I have above 150 men
"at work, and only one overseer under me, beside the under-
"takers, who are mere tyros, and require constant watching.
"The remainder of my time is taken up partly by head-aches
"and other bad health, and partly by consultations on various
"subjects, of which I can have more than I am able to answer,
"and people pay me pretty well. In short, I want little but
"health and vigour to make money as fast as is fit.

"Now, Doctor, if you and your friend Hygeia can impart
"to me those blessings, I may be a rich and happy man:
"otherwise, I can scarcely be either. I expect soon to have
"another touch at the engine."

In December, 1770, he writes: "Notwithstanding the despe-

" rate weather I am almost constantly at the canal. It costs " me many a fit of chagrin; shows me many of my imperfec- " tions, &c.; but for all that, I find myself more strong, more " resolute, less lazy, less confused than I was when I began it. " However, I have no abatement of my headaches, in quantity " or quality. I found the other day," he soon afterwards adds, " upon considering my circumstances, that, supposing " the engine to stand good for itself, I am able to pay all my " debts, and some little thing more; so that I hope in time " to be on a par with the world. But I must say that my " present life is a life of much vexation, besides bodily fatigue, " of hunger, cold, wet feet, &c., which I could not endure had " I the least of the gout, the gravel, or many other diseases. " I don't know how it is, but I think my health rather better " in these gloomy months of December and November than it " was in summer. I have a hundred men at work just now, " finishing a great hill we have wrought at this twelvemonth. " The nastiness of our clay-grounds is at present inconceiv- " able; the quantities of rain have been beyond measure."

" Our canal has not stopped, but is likely to do so, from " our having expended the subscription of 10,000*l.* upon seven " miles of the navigation, and having about two miles yet to " make. We have, however, made a canal of four feet water " for one of three feet subscribed to, and have also paid most " abominably for our land.

" I decline only being the manager, and not being engineer. " I wrote you before how grievous that first part of the busi- " ness was to me, and it daily becomes more so. Everything " has been turned over upon me, and the necessary clerks " grudged to me; I am also indolent, and fearfully terrified " to make bargains, and hate to settle accounts. Why there- " fore shall I continue a slave to a hateful employment, while " I can otherwise, by surveys and consultations, make nearly " as much money with half the labour, and, I really think, " with double the credit? for a man is always disgraced by " taking upon him an employment he is unfit for. I have no " quality proper for this employment but honesty, which re- " proaches me for keeping it so long.

“ Remember in recommending me to business, that what I “ can promise to perform is, to make an accurate survey and “ a faithful report of anything in the engineer way; to direct “ the course of canals; to lay out the ground, and to measure “ the cube yards cut, or to be cut; to assist in bargaining for “ the price of work, to direct how it ought to be executed, “ and to give my opinion of the execution to the managers “ from time to time. But I can upon no account have any- “ thing to do with workmen, cash, or workmen's accounts, “ nor would I choose to be so bound up to one object that I “ could not occasionally serve such friends as might employ “ me for smaller matters. Remember also I have no great “ experience and am not enterprising, seldom choosing to “ attempt things that are both great and new; I am not a “ man of regularity in business, and have bad health. Take “ care not to give anybody a better opinion of me than I “ deserve; it will hurt me in the end.” *

“ The cheapness of your canal,” observes his able and zealous friend and correspondent, “ astonishes me who have “ contributed to pay about 4500*l.* for each mile of another, “ which, locks excepted, had no difficulties to be compared “ with those you have surmounted. Among other instances “ of our wisdom, we have employed engineers, clerk, head- “ carpenters, &c. in such swarms, that their salaries have “ amounted to 1200*l.* per annum. And yet so invincible a “ propensity have mortal men to being duped, that the “ strongest and clearest remonstrances, and even want of “ money, could not enlighten us. But let that pass. I shall “ take care that the difference of your management shall be “ known.”

“ You complain,” he says a fortnight later, “ I have not “ been sufficiently particular about our canal. As to the “ canal itself, it will, I hope, by Christmas be complete for “ seven miles, and of immediate and profitable use, because “ even from that termination we can afford to undersell “ others.”

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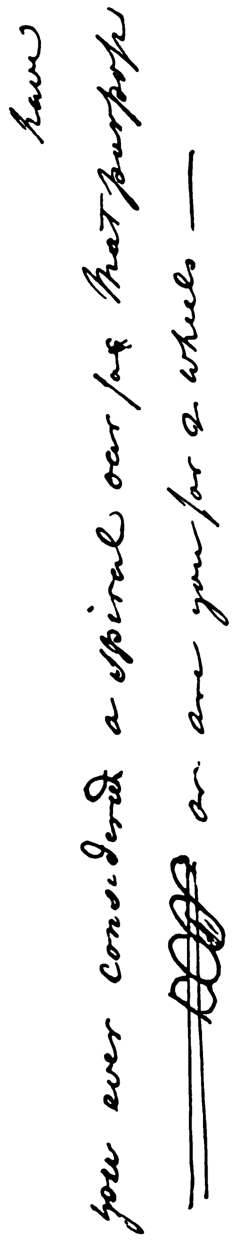
* To Dr. Small, 7 November, 1772.

[Then follows a particular description, with measurements in cubic yards and superficial feet respectively, of the various cuttings, embankments, bridges, tunnels, and other works of the canal.]

"Our whole expense, act, surveys, &c., will be about " 10,000*l.* spent. I have surveyed, levelled, planned, staked " out, and measured the cube yards cut, of the whole, per- " sonally; I have also made bargains, superintended the work " and accounts, and by myself and one clerk paid the cash. " I have to the bargain been obliged to oversee every piece " of work that was in the least out of the common road. " I am now, in spite of a most [inclement] season, from " five to six hours in the fields every day, and ride about " ten miles. This is the one side. On the other, I am ex- " tremely indolent, cannot force workmen to do their duty, " have been cheated by undertakers and clerks, and am un- " lucky enough to know it. The work done is slovenly, our " workmen are bad, and I am not sufficiently strict. I am " happy in the friendship of the principal residing proprietors, " and am welcome to their houses as to my own, otherwise " my wretched health could not have borne the fatigues I " have undergone. What provokes me most is, that I am " sensible that most people could in the same time have done " much more and better work, possibly with as little trouble " to themselves. I would rather face a loaded cannon than " settle an account or make a bargain. In short I find my- " self out of my sphere when I have anything to do with " mankind; it is enough for an engineer to force Nature, and " to bear the vexation of her getting the better of him. Give " me a survey to make, and I think you will have credit of " me; I can draw tolerably; set me to contrive a machine, " and I will exert myself; in whatever way you choose to " employ me, I shall endeavour to follow your advice."

For two years and a half, from June, 1770, to December, 1772, Mr. Watt filled his office of engineer to the Monkland Canal, at his salary of 200*l.* per annum; which he considered a liberal allowance, and which he only resigned on the completion of that work, and his increasing engagements in other business of a similar kind. It was in the course of his correspondence in regard to these canals, that Dr. Small having mentioned the desire which Mr. Boulton and he entertained of moving canal-boats by the steam-engine, (which they at first proposed should be on the high-pressure principle):—"*Have you,*" says Mr. Watt in his reply, "*ever considered* A SPIRAL "OAR *for that purpose, or are you for* "*two wheels?*"[*] And, to make his meaning quite plain, he accompanies his question by this rough sketch of A SCREW PROPELLER: even in the number of turns of the spiral not differing very greatly from such as in our own days, from a wide range of the most careful experiments, have been found to be best fitted for the purpose. The accompanying woodcut gives a faithful facsimile of the remarkable passage in which this idea was started, and which so well deserves to be considered as adding another laurel to those which already adorn the name of Watt.



have
you ever considered a spiral oar for that purpose
or are you for 2 wheels —

Unfortunately for the success of the project at that time, Dr. Small in his reply observed,—"I have tried models "of spiral oars, and have found them "all inferior to oars of either of the "other forms; I believe, because a cy-"linder of water immersed in water can "be easily turned round its axis. This, "I dare say, you perfectly know, so "more need not be written. * * "* * It is a great misfortune

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[*] To Dr. W. Small, 30th September, 1770.

"that spiral oars are but indifferent." Dr. S. appears to have understood the proposal as being for two oars, one on either side of the boat; whereas there can be little doubt that Mr. Watt, from using the singular, "a spiral oar," as opposed to *two* wheels, as well as from the very distinct explanatory sketch which he added with his pen, intended his propeller to work at the stern, as a boat is sculled by one oar. Thus, however, did it happen, that the project of the screw-propeller, to be worked by his own improved steam-engine, was propounded by James Watt *eighty-eight years ago;* that, when propounded, it was, by the discouragement of his friend, abandoned, or at least left *in retentis;* and that only his suggestion of it has remained, to be disentombed at this distance of time, as a fresh instance of his singular ingenuity and foresight, and as one of the greatest curiosities of what may already be termed the traditional history of engineering antiquity!

In 1770, also, he was employed by the Trustees for the Annexed Estates, (or the estates which in Scotland had been forfeited to the Crown by the attainder of their owners for participation in the rebellions of 1715 and 1745), to make a survey for a canal from Perth to Cupar of Angus:—"I wrote "you from Perth," he says to Dr. Roebuck,* "on Sunday "last, since which time I have been close employed viewing "this country and examining which would be the proper "track for the canal, which I begin to survey to-morrow. "You will, perhaps, think a week a long time to look about "one; but it appears possible to make a canal from the hill "of Kinnoul (opposite to Perth) to Forfar, which will measure above 36 miles, and that without a lock. There is a "great deal of rough ground betwixt Perth and this place, "but from hence to Forfar the ground is as well adapted as "may be expected in any country. This valley of Strathmore is about 18 computed miles in length and six in "breadth, but not a dead flat, as we imagined; the soil in "general good, and of all kinds, from sand and gravel to

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* From Cupar of Angus, 15 April, 1770.

" clay, though I have seen none so strong as the Kerse clay, " and very little of the country so flat. Agriculture is more " advanced here than in some more southern parts of Scot- " land. There are some small proprietors of land, but it " mostly belongs to great lords. There is here a great spirit " of improvement; and great abundance of shell marl, but " no fuel, except what is brought from Dundee over hills. " * * I have had my health very well here, though " much fatigued, and sometimes very cold with the piercing " winds from the snowy Grampians that form the north side " of this valley."

" My stay in Strathmore," he continues,* "was much " longer than I expected. I had to examine and survey a " country of 36 miles in length, and to hunt about for a course " for a canal through country where Nature had almost done " her utmost to prevent it;—indifferent health, and weather " viciously cold and stormy, were the attendants on my " survey. The winds from the snowy Grampians, and snow " even in the valleys a foot thick on the 10th of May, con- " vinced me of the utility of what I was about;—for nothing " can be more dismal than such weather in a country which " nature and art have deprived of fuel."

And, thirty-six years later, in answer to the Earl of Breadalbane, who, as chairman of a Committee for making a navigable communication between the Tay and Loch Earn, had applied to Government for part of the balances remaining from the forfeited estates, on the ground that such a grant had been in contemplation by the Board of Annexed Estates, and was prevented from being carried into effect only by the dissolution of the board on the restoration of those estates, he wrote,†—"I never made a *survey* from the " Tay to Crieff and Loch Earn; but, at the desire of some " gentlemen of that neighbourhood, I rode over the ground " from the Linn of Campsie to Crieff, when I was making a " survey from Perth to Forfar, (I think at the expense of the " Trustees for Fisheries and Manufactures), and found that a

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* To Dr. Small, 9 September, 1770.

† 12 May, 1806.

"canal in that line was apparently very practicable; but it "has occurred to me since, that the proper line of canal "would be up the valley of Strathearn, from near the con- "fluence of the Earn with the Tay; as it would by that "means extend its influence over a greater tract of fertile "country, and avoid the banks of the Tay, which, as far as "I remember, are in many places very steep between Perth "and the Linn of Campsie. But, as this view was taken so "long ago as the year 1770, my memory upon the subject "cannot be much depended upon."

In the same year, 1770, in which he made his survey in Strathmore, Mr. Watt made a survey, and drew out regulations for the contractor, for building a bridge over the Clyde at Hamilton:—"I have lately made a plan and estimate of a "bridge over our river Clyde, eight miles above this; it is to "be of five arches and 220 feet water-way, founded upon "piles on a muddy bottom."* He also made a survey and report on the declivities and state of the bed of that river, by desire of the magistrates of Glasgow, who were then engaged in endeavours to improve its navigation and deepen its channel; endeavours which have ever since been strenuously sustained, and have met with well-deserved though then quite unexpected success.

The names of the other engineers with whose Reports on the same subject that of Watt has thus been associated, viz. Smeaton, Golborne, Rennie, Whidbey, Clark, Hartley, and Walker, bear conspicuous testimony to the advancement which Mr. Watt was now rapidly attaining in such pursuits, as well as to the clear-sighted discernment and public spirit of those who thus employed him. The progressive and extraordinary increase of the opulence and commercial consequence of Glasgow as a port, has most signally manifested the advantage of such engineering operations, when conceived with sagacity, directed by a spirit of liberality, and executed with energetic vigour. Of this, no stronger proof can be given, than the fact that whereas in 1770 and eighteen previous years the revenue arising from harbour-dues, &c. on the Clyde at Glasgow did not exceed 147*l.*, in 1853 it amounted, as shown by the accounts of the trustees of the river, to no less a sum than 86,580*l.* The rate of increase is exhibited in the following table, supplied by the Treasurer to the Trustees, and on the accuracy of which, therefore, the fullest reliance may be placed:—

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* To Dr. Small, 21 December, 1770.

"CLYDE NAVIGATION. REVENUE.

	£.		£.
"1752, to 1770	147	"To 1820	6,328
„ 1780	1,515	„ 1830	20,296
„ 1790	2,239	„ 1840	46,536
„ 1800	3,319	„ 1850	64,243
„ 1810	6,676	„ 1854	86,580."

We must add that the sum of 147*l.*, stated as the revenue from 1752 to 1770, is the *whole* sum entered as having been received on that account in all those eighteen years;—"if "more than this," says the Treasurer, "was drawn, it cannot "have been properly entered or accounted for." The average revenue at that time, therefore, cannot be held to have been more than a fraction over 8*l.* *per annum*, or *not sixpence a day*. When we contrast this insignificant sum with the princely income realised from the same source in our own time,—showing an increase of more than ten thousand-fold,—we are forcibly reminded, on the one hand, of the feeble spring or tiny rill of the solitary moorlands, and, on the other, of the magnificent estuary, surrounded by a vast and thriving population, and bearing to and fro, in endless succession, the proud navies of merchandise and war.

It appears also from authentic returns of the date last mentioned in the table, that during twelve months alone, thirty-two shipbuilders on the Clyde constructed and contracted for no fewer than 266 vessels, of the aggregate tonnage of 168,000 tons, (thus averaging fully 630 tons each); for which engines were prepared of 29,000 horse power. "This gigantic work," said the American Consul at Glasgow, in his address to the magistrates of that city on a great public occasion, "throws your competitor Liverpool, and even "colossal London and her famous Thames, into the shade."

Well, then, may the ancient city, though the "Salmon-"fishings" have long been severed from her see, retain in her armorial bearings the fish and jewelled ring of Kentigern—emblems of her productive river; and long may her motto, as heretofore, auspiciously prevail—"LET GLASGOW "FLOURISH!"

In 1771 he gave in a Report on the best means of improving the harbour of Ayr, and made a survey for a canal of junction between the great (Forth and Clyde) canal and the harbour of Borrowstoness. In the same year he also surveyed lines for canals of junction between the Frith of Clyde and the Atlantic, at Crinan and at Tarbert, for the Commissioners for managing the Annexed Estates; his Report on those two lines being prepared and delivered in the following year. In 1773 he made a survey of a canal from Macrihanish Bay, on the western coast of Argyleshire, to Campbelltown, for the conveyance of coals; also of a canal from Hurlet to Paisley, and of the channel of the Water of Leven; as well as a survey, by desire of the Lords Commissioners of Police, for the purpose of rendering navigable the rivers Forth, Gudie, and Devon. To these were added a number of plans, mensurations, levellings, and estimates, at the request both of corporate bodies and of private individuals, which need not here be further particularised;—although among the number were some of very considerable local importance, such as plans for Port-Glasgow Docks and Harbours, 1769–1772; for supplying the town of Greenock with water, 1772–1773; &c. &c.

But the last and most remarkable of his civil-engineering works was that which he was called on, also in 1773, to perform for his employers the Commissioners of Police; viz. a survey and estimate for a navigable canal, to pass through the chain of rivers and lakes in the wild and remote tract of country between Fort William and Inverness; being the same line in which, at a considerably later period, the celebrated Caledonian Canal was successfully constructed by Mr.

Telford. The first notice we find in his correspondence relative to that great work, is in a letter to him from Dr. Small, dated 1 May, 1773:—"Your very pleasing friend Mr. Hamilton was here on Thursday last, but could not stay. * * He told me you were to make a canal at Cantire. Of late a project has been talked of in England of making a passage for ships from Inverness to the Western Sea. It is said that it might be done easily, for that the ground between the two lakes, Ness and Oich, is level. Could you possibly survey this and judge of it, we could contrive to render the survey useful to you perhaps. Consider, and if possible do it before you come hither."

In answer to which, Mr. Watt writes:*—"In relation to your Inverness navigation, I know something about it. It would cost much money and time to make such a survey as I could set my hand to, and I am afraid the estimate would frighten you. The ground between Loch Oich and Loch Lochy is 50 feet high, and probably hard ground; the whole height, deducting the said 50, is 110 feet, the country hilly and rocky, few inhabitants, and labour very dear. I would like well to survey it, if paid for it; but I like better to come and visit you."

"The reasons," rejoins Dr. Small,† "for my pressing you to consider the project for joining the lakes were these:—It has been published by Pennant that an almost level course might be found for a canal. Your survey would be the first, and as things *now* stand, both you and it could be warmly commended to Lord Dartmouth, who is at the head of the Council of Trade, to Lord Sandwich, the First Lord of Admiralty, and to Lord North. Changes may in one year, you are very sensible, ruin these possibilities. The object is of great importance, and is tolerably well understood to be so, and may be further explained so as to be rendered popular. Advantages might arise from your having only proposed such a scheme to those great men, and having been shown to be most fit for executing it."

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* 20 May, 1773.

† 2 June, 1773.

And, on the 17th of August in the same year, "I am "appointed," writes Mr. Watt, "by the Court of Police to "make a survey of the canal from Inverness to Fort William, and set out the week after next. I accepted of this "merely in consequence of your desire, otherwise I should "have delayed it till next season. I send you two covers; "you forward your instructions and ideas of the utility in one "of them, and your letter will probably reach me at Inverness, to which place it will be forwarded from Glasgow in "case of my being gone."

Dr. Small's "ideas of the utility" of the projected canal were very clear and simple; and on the 29th of September he thus gives them, although prefacing the statement with an account of a long fit of weakness having greatly disabled him from writing:—"When the herring-fishery was attempted "by the people on the eastern coast, they found their own "sea furnished neither plenty of the fish, nor fat ones; therefore they tried to send vessels to the Western Sea. At the "best season, these ships could seldom get round by the "Orkneys, on account of periodical westerly winds and currents; and the voyage through the two channels is long "and dangerous. Had the canal then existed, I believe the "fishery would by this time have been established; and for "want of it, besides the disappointment in that contingency, "a vast number of the fishing people that used to swarm "upon the eastern coast have left the kingdom, the people "having changed their diet, and now using less fish. Besides, "it was necessary, on account of the nature of the voyage, to "use too large and expensive vessels.

"Next, could a canal be made to admit armed vessels, no "enemy could ever venture into the Irish Channel, or near "the Western Isles.

"The returning voyage, even to London from America, "would be shortened one-third upon an average, by steering "round the North of Ireland for this canal, on account of "the wind in those latitudes. The banks of the canal would "prove a seminary of herring-fishers, whale-fishers, and New-

" foundland-fishers, for canals tend more to breed watermen " than even sea-towns.

" More artisans living on the eastern coast of Scotland than " on the western, and they daily growing more expert, they " would have more easy access to the American market, the " only one that is likely to be long supplied with manufactures " from Britain, &c. &c. besides all the inland advantages."

Before his survey was completed, Mr. Watt was suddenly recalled to Glasgow by a grievous domestic calamity, of which we shall hereafter more particularly speak; but he then wrote to Small:—" As far as I saw of the canal, it is practicable. " Loch Oich is 100 feet above the sea, and the summit of " Lagan na Drum, that separates from Loch Lochie, only " 20 feet above Oich, and all good gravel. There is plenty " of water, and Oich 4 miles long for a reservoir. I left " Morison, my surveyor, who is tolerably accurate, to complete the survey. I had a miserable journey home, through " the wildest country I ever saw, and the worst conducted " roads: an incessant rain kept me for three days as wet as " water could make me. I could hardly preserve my journal-" book."

" Pray does the country you have surveyed," replies the Doctor, " furnish timber fit for ship-building, or wood for " charcoal, or mines of any valuable kind? I had no suspicion that Loch Oich was so far above the sea, and therefore had hopes that ships might be built in it, and their " cannon, ballast, &c., might be cast on its banks, and their " bolts, &c., be made there. Could many small canals be cut " from the lakes and the great canal, on both sides; I mean " such as could carry boats from one to three tons burden? " You say the road from the fort is badly planned. Pray " mention this to the Commissioners of Police, who I understand are your present employers. It may produce both an " improvement and employment for you for years." " I do " not wonder the people migrate from the country you have " described, to America, or anywhither. Pray have not " all these mountains formerly been forests, and why does

" not timber now grow upon them, as they are not cultivated? Nothing but *incessant* cultivation can hinder " any spot in America, from latitude 50° southwards, from " producing trees. I am led by this and many other reasons to suppose, nay to believe, that the frozen space of " the globe is annually increased, at the rate of about the " 300th part of a degree of latitude at a medium, or more; " so that after a certain number of years all Europe, and " finally the whole surface of this earth, will be frozen, as the " moon is now and has long been. *Voilà une théorie;* one " good property of which is, that I shall not live to suffer the " disgrace of seeing it refuted by experience. And then it " ought exceedingly to forward the execution of my project " for producing perpetual summer; of which I will be bold " to say, that if all the gunpowder which has been spent by " their Imperial and Royal Majesties the Emperors and Empresses of Constantinople, Germany, and Russia, the Kings " of France, Spain, Britain, and Prussia, within these last " twenty years, had been laid out upon it, the powder would " have produced at least as much benefit to every one of them " as it has done by being expended on their own schemes. I " have had thoughts of writing a circular letter to these potentates, and if you give me any encouragement, notwithstanding my laziness, I will still do it, although there is but little " to be made of kingly heads, I fear."*

" As you are a great advocate for the Inverness Canal, and " main adviser for my undertaking the survey," again writes Mr. Watt, " now I find myself in a kind of scrape, I must " call upon you to help me out. The case stands thus:— " Freight from Forth to Clyde and back, 20*s*. per ton; time " of passage from 10 to 40 days; ordinary passage 20 days. " Distance by outside Orkneys 635 geographical miles; by " Pentland 575. From Buchan-ness to Mull by Orkneys " 375; by Pentland 315. By the canal, distance by sea, " Buchan-ness to Inverness 105; artificial navigation 23 " English miles; Freshwater loughs 30½ geographical ditto;

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* 27 October, 1773.

"Fort William to Mull 30 ditto. Average rate of vessels "sailing, founded upon a twenty days' passage, 30 miles per "diem. Passage, Buchan-ness to Mull by Orkneys, 12½ "days; by Pentland, 10½. Time of passage by canal, the "sea part 135 miles, 4½ days; the loughs one day: the four "canals, 23 miles, two days: total by canal, Buchan-ness to "Mull, 7½ days. Saving over Orkney passage five days; "over Pentland passage three days. Summer insurance "round Orkney 30*s.* per cent.; winter ditto about 3*l.*; but "no wise under-writer will put his name to such a policy. "Winter insurance from Clyde to Fort William 25*s.* per "cent.; from Murray Firth to Leith 20*s.* The expense of "making a canal for 10 feet water will be about 160,000*l.*, "besides land. *Voilà les faits.* I want your opinion of the "proper method of proving the advantages and valuing them "in money, so that it may appear what toll can be afforded, "and whether it will compensate the expense. Be as full as "you please; for unless some strong arguments appear, I "am afraid, as a just judge, I must myself pass sentence of "condemnation, or leave the poor canal to the mercy of the "public.

"Give me your opinion of the best manner of digesting a "report of this matter, and of the size of the plan. I think "of doing it in one long plan, upon a scale of an inch to the "mile; it will be five feet long, and may be printed in three "pieces, if it merits that expense. A lesser scale would not "show the parts, and a larger would not show the connection.

"Since my last I have been close writing upon this subject."

"I have now finished," he adds,* "my reports and plans "of the Inverness Canal, and have sent a copy of them to "Lord C[athcart], who would not fail to show them about. "The principal copy of the report I only finished this week; "that I sent to Lord C. was only an outline."

The great engineer, Mr. Telford, throughout the whole of his lengthened labours in connection with so vast an undertaking, has borne testimony to the particular correctness and value of Mr. Watt's survey; a circumstance which will be our sufficient excuse if for a moment we anticipate the course of our narrative, to explain the gratifying circumstances in which Mr. Watt at length witnessed the completion, on an enlarged and magnificent scale, of that great national work, on behalf of which his early skill and energy had thus been enlisted. He had also in the meantime[*] been consulted, as to the same line, by Mr. Rennie; whose scheme, however, was not then carried out.

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* To the same, 9 April, 1774.

On Telford's return from Scotland towards the end of the year 1801, he wrote to Mr. Watt, informing him that he had been engaged there since the month of July, employed in making surveys by order of the Treasury Board, one of the objects prescribed to him being to examine the country from Loch Linnhe to Inverness, as to the practicability of making an inland navigation; and expressing a strong desire to see Mr. Watt's earlier survey of that district, in order by it to correct his own observations. His letter[†] concludes:—"We "cannot spare you yet; you have done much good, and you "must do more still. I cannot positively insist upon your "personally making good the Spanish compliment, 'Live a "'thousand years,' but I may safely presume that your name "will deservedly live for ever." "I have so long accustomed "myself," he adds in a subsequent letter,[‡] "to look with a "degree of reverence to your work, that I am particularly "anxious to learn what occurred to you in this business while "the whole was fresh in your mind. * * The object appears "to me so great and so desirable, that I am convinced you "will feel a pleasure in bringing it again under investigation; "and I am very desirous that the thing should be fully and "fairly explained, so that the public may be made aware of "its extensive utility. If I can accomplish this, I shall have "done my duty; and if the project is not executed now, "some future period will see it done, and I shall have the "satisfaction of having followed you in promoting its success."

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[*] Mr. Rennie to Mr. Watt, 19 May, 1793.

[†] Mr. Telford to Mr. Watt, 6th December, 1801.

[‡] Mr. Telford to Mr. Watt, 17th December, 1801.

In 1802 also he again writes to Mr. Watt that he had found an abstract of his Report published in a Report which Dr. Anderson made to the Lords of the Treasury:—"I believe it "is yours," says Mr. Telford, "because it is just and masterly; and I have introduced in my Report your general "description, plainly saying that it could not be so well told "in any other words."

Mr. Telford says that, on comparison, he found the whole of Mr. Watt's statements in his survey "particularly correct, "except in the fall from Loch Oich to Loch Ness, where we "differ a few feet; but the states of the water in the Lochs "make some difference, and the only bad weather I experienced was during this part of the survey, so that I am not "positive that I am right. I had not time to prove the "levels, nor is it of much moment: the height of the water "in Loch Oich above the tideway is 100 feet, as near as may "be."* To which Mr. Watt replied:—"As we agree upon "the level of Loch Oich the summit, any difference of level "elsewhere cannot materially affect the estimates, as the feet "of lockage will remain the same. The mistake may, however, be mine, as my levels were not repeated."†

The depth of water recommended by Mr. Telford was 22 feet. That of the canal as executed was in most parts 15 feet; although the bridges and locks were prepared on a scale to admit of that being increased, should it ever be found advisable, to 20 feet. Mr. Telford introduces a long extract from Mr. Watt's Report, with the following observations:— "In the year 1773, the Trustees for the Forfeited Estates "employed Mr. Watt to make a survey of this track, which he "did, and furnished them with a report and estimate of the "expense of making a canal of ten feet water. This report "is so able and just, that had I considered that size of canal "as most advisable, I should have adapted the calculations of "the expense to the present day, and mentioned some alterations which have taken place in the country since his

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* Mr. Telford to Mr. Watt, 3 May, 1802.
† Mr. Watt to Mr. Telford, May 9, 1802.

" survey was made, and should have recommended the survey " to your Lordships' attention. But Mr. Watt's views were " merely to ascertain how far a navigation of any sort was " practicable, and therefore he fixed upon ten feet of water " as an assumed standard to enable him to make his estimates. I lose therefore the benefit of his particular calculations; and I am under the necessity of departing, in some " instances, from his line of canal, especially at the entrances " into the lochs and tideways, in order to obtain a greater " depth of water; but I have followed him wherever the circumstances would permit; and I cannot resist the introducing his general description of the country through which " the navigation is proposed to be made, because, after having " examined the whole with care, I find it to be so correct, " that I could only repeat the same descriptions and dwell " upon the same points." Their levels agreed within one foot.—See p. 42 of the Report. In his Report,* Mr. Watt mentions that he confined his estimates to a canal of ten feet depth of water, because he knew of none that had been executed upon a greater scale, and because his views in making the survey were principally directed to those dimensions. "It is sufficient," he adds, "in a first survey, that " the possibility is established, and the expense of one mode " of communication is nearly estimated, which I flatter myself " I have done. If from my observations the making any " communication should appear an eligible scheme, the matter " may be minutely examined, and the opinions of other artists " obtained, concerning the best mode of execution."

It is curious, if only by way of contrast with the practice of the present day, to record the rate of payment at which the skill and exertions of a man endowed with Watt's powers of mind were then obtained. The Strathmore survey of 1770 may be taken as a specimen. On that occasion he was actively engaged in travelling and in field operations for forty-three days, usually from eight or nine in the morning till seven or

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[*] Third Report on the Survey of the Coasts of Scotland, ordered to be printed 14th June, 1803, Appendix, p. 32.

eight at night, during most inclement weather, with piercing cold, and frequent and heavy falls of snow and rain; and his exertions so much exhausted his strength, as to render him, to use his own words, "unable for some time to apply him-"self to any other business that required attention." His charge for that work was 80*l.*, or about 1*l.* 17*s.* per diem, *inclusive of all his expenses of travelling and living.* For the preparation of the Report and directing the execution of the map which accompanied it, he was paid the further sum of 30*l.*—an almost equally insignificant recompense for the mere amount of time and labour bestowed, independent of all considerations of superior knowledge, accuracy, and sagacity.

That the rate of remuneration of civil engineers did not rise in any very rapid ratio in the latter part of the last century, appears from a letter of Mr. Watt in 1791, in which it is incidentally mentioned that Mr. Rennie, "who is in con-"siderable fame, and, I suppose," says Mr. Watt, "as well "paid as any of his standing, has two guineas a-day when "employed as an engineer;" in addition, however, it is to be presumed, to his travelling expenses and other "costs and "outlays," which was not the case with the smaller rate of pay of Mr. Watt in 1770.

We have in our own time seen engineering bills, in which the rate of charges presented a marvellous contrast to those which men such as Rennie and Watt felt it right to make; while it was also found, to the further serious cost of those who had to defray the far larger amount, that the services received by them for their money were of very far less than equivalent worth!

CHAPTER XVI.

PHILOSOPHICAL PROBLEMS — TIME-PIECES — MICROMETER AND DIVIDING-SCREW — SURVEYING QUADRANT — BAROMETERS — MICROMETERS FOR MEASURING DISTANCES — HISTORY OF THE INVENTION OF MICROMETERS — SIR DAVID BREWSTER — DE LA HIRE — MALVASIA — AUZOUT AND PICARD — GASCOIGNE — MORIN — ROCHON — MASKELYNE — DEATH OF MR. WATT'S FIRST WIFE.

Besides all his surveying and civil-engineering, and the manifold alterations he devised in both his condensing and his wheel engines, Mr. Watt bestowed, during the years of which we have now been speaking, in concert with his friend Small, a good deal of thought on various other ingenious mechanical contrivances, which supplied pleasant amusement to their inventive and reflective brains. "We have "abundance of matter to discuss," says the great engineer; "though the damned engine sleep in quiet!"* "The French, "you know," says Small, "offer large præmia for time-keepers. "Were I idle, I should try to win one of these. But physic "exhausts my whole faculties, and pays but indifferently. I "am so made that I suffer no fatigue from thinking ever so "long and attentively on a subject in which I can get for-"ward; but if I am absolutely puzzled, and see no clue, my "head turns round, and I speedily become more tired than a "galley-slave. Physic very fortunately furnishes abundance "of these profitable points."† "I have perfected my clock "with one wheel of nine inches diameter, which is to tell "hours, minutes, and seconds, and strike, and repeat, and be "made for thirty shillings."‡ And again, "My clock of one "wheel, that shows hours, minutes, and seconds, and strikes "the hours and repeats them, is nearly finished. The striking "and repetition are good, the rest is gimcrack."§

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* 7 November, 1772.

† 5 October, 1770.

‡ 14 February, 1771.

§ 16 December, 1771.

"You wrote me before," says Mr. Watt,[*] "of your clock "with one wheel. Did I ever mention to you a striking "part, regulated by a balance pendulum with live scapement, "which had only one wheel?" But some months later;[†] "Everybody," says Small, "is too much engaged for the "prosecution of schemes, so that even my clock is not prosecuted, and I have only one, which I cannot send to you;"— "I have just ordered a pendulum clock to be made with no "wheel at all;"[‡]—and, "when my clock with one wheel," he afterwards adds,[§] "was finished, I found it too complicated, "and have now got one with no wheel, and only one sector "with seventy-five teeth. It strikes, repeats, shows hours, "minutes, and seconds, and goes eight days, with the usual "descent of the weight. This is to be ranked in mechanics, "as riddles and rebuses are ranked in poetry."

On which comes this comment of the sagacious Watt:— "As to clocks, I do not fully conceive how you can make "yours go eight days with the ordinary descent of the weight, "unless by pulleys or something equivalent, which would only "be a quibble upon a wheel;"[‖]—thus answered by the inventor:[¶]—"there is no quibble in my clock, and we have "now found a tolerable workman for the execution of it. "One is now making, which will show with much more accuracy than any other clock has hitherto done, the spheric "phenomena relating to astronomy, sidereal and mean time, "hours, minutes, and seconds, with only one wheel and one "sector. It will also strike and repeat the hours. The wheel "has 72 teeth and the sector 75 only;"—"I have had a new "scapement made for watches, of such marvellous virtue, that "if the maintaining power is quadrupled, or decupled, the "number of the vibrations will be lessened, but not above ten "in twenty-four hours."[**] And—"I have taken out a patent "for improvement on clocks and other time-pieces, and want "you vastly to help me to draw up the specification, which

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[*] 24 December, 1771.

[†] 11 July, 1772.

[‡] 16 November, 1772.

[§] 3 December, 1772.

[‖] 17 January, 1773.

[¶] 27 January, 1773.

[**] 15 March, 1773.

" must be given in soon. I have made a church-clock, consisting
" only of one wheel of 126 pins, and one sector of 75
" pins, and a hammer, with a scapement for the sector and
" another for the hammer. It strikes the hours, shows hours,
" minutes, and 20th parts of minutes, and goes eight days.
" And I have given drawings of a pocket-watch, which is to
" consist of one wheel and two sectors, and is to show hours,
" minutes, and seconds, and to have only 142 pins in the
" whole watch, and to have no chain nor fuzee, the kind of
" scapement rendering them unnecessary. But I have had
" hitherto villainous bad workmen. The axis of the pendulum
" of my clock is a cylinder, and rolls upon curves, which
" render the vibrations isochronous, and it has two rolls for
" one impulse."*

"A patent," he again writes,† "has been taken out for my
" clocks and watches, and there is reason to hope they may
" become an article of commerce. I am ready to make over
" to you all my interest in the patent, provided that can be
" done so as to benefit all concerned, which, if you can be
" established in this country, might be the case."

"As to gimcracks," writes Mr. Watt,‡ "I have contrived a
" new micrometer, made by drawing two converging lines
" upon glass. I believe from trial it will answer. I mentioned
" a dividing-screw; it has a wheel fixed upon it with
" 150 teeth and only $1\frac{1}{4}$ inch diameter: it is moved any
" portion of a turn or number of turns by a straight-line rack,
" the teeth of which fit it, without shake, and is moved by
" the hand or foot. It divides distinctly an inch into 400
" equal parts." Of the micrometer, we shall soon give a full
history. "As to your doubts about the screw," he writes to
Small, "I intend to annihilate them when I see you:"—"my
" dividing-screw can divide an inch into 1000 tolerably equal
" and distinct parts on glass;"—"I had occasion to use my
" last dividing-screw for the first time the other day. It
" divided 9 inches into 20ths, and did not err the $\frac{1}{200}$th of an

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* 27 October, 1773.

† 29 March, 1774.

‡ 24 November, 1772.

" inch in the whole 9 inches. I did not find that there was
" the least inequality among the divisions, though I subjected
" them to the most severe trial, and I have found a way by
" which I can divide a foot into $\frac{1}{1000}$ths of an inch without
" erring above $\frac{1}{200}$th of an inch in the whole length, and the
" divisions shall be equal among themselves; so that I reckon
" that machine exceeding near perfect, and find it very useful,
" as it saves much needless compass work, and, moreover, can
" divide lines into the ordinates of any curve whatsoever."
" I rejoice in all your improvements," replies Dr. Small,*
" but have many optical difficulties that lessen my confidence
" in observations made with the most accurately divided instruments.
For example, no optical instrument hitherto constructed,
catoptric or dioptric, or catadioptric, produceth an
" exact copy of any object; so that all the visible points of
" every object of sensible apparent diameter are represented
" in the field of the instrument in situations in relation to
" each other very different from what they ought to occupy,
" &c. &c. The *unsteady* refractions of light passing through
" the atmosphere are also vile things; not those mentioned
" by astronomers only, but others I will show you when
" we meet."

"I am making a new surveying quadrant by reflection," writes Mr. Watt,† "having the uses of a semicircle as
" taking angles to 180°; the principle, that of Bird's octant,
" in which the objects are only once reflected. In this I am
" making, the fixed glass stands at 45° to the first radius;
" and by shifting the place of the eye, the head is never in
" the way. I am going to make another altogether of glass,
" with nonius of the same."

On which, Dr. Small observes:—"I remember to have
" much admired your schemes about improving instruments
" for measuring angles by reflected light. Dollond has lately,
" as I have heard, made some inconsiderable but saleable
" alterations of Hadley's Quadrant, as it is called, though the
" invention is Newton's, which you no doubt know." Dr.

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* 29 March, 1774.

† 17 January, 1773.

Small was quite correct in his account of the history of the invention of that most valuable instrument; for Sir John Herschel speaks, in his 'Treatise on Astronomy,' of "the "sextant, or quadrant, commonly called *Hadley's*, from its "reputed inventor, though the priority of invention belongs "undoubtedly to Newton, whose claims to the gratitude of "the navigator are thus doubled, by his having furnished at "once the only theory by which his vessel can be securely "guided, and the only instrument which has ever been found "to avail, in applying that theory to its nautical uses.

"Newton communicated it to Dr. Halley, who suppressed "it. The description of the instrument was found, after the "death of Halley, among his papers, in Newton's own hand-"writing, by his executor, who communicated the papers to "the Royal Society, twenty-five years after Newton's death, "and eleven after the publication of Hadley's invention; "which might be, and probably was, independent of any "knowledge of Newton's, though Hutton insinuates the "contrary."*

So also Oltmanns has said, "John Hadley fit construire le premier sextant à réflexion, dont l'invention appartenait à "Newton."†

Small then continues:‡—"I am attempting the improve-"ment of telescopes, and still more anxiously of microscopes, "because the present microscopes deceive their users; but "I find it very difficult to procure good lenses. Could you "make an achromatic lens of half an inch focal distance? "Dollond's patent is out."

In return, says Mr. Watt: §—"I have invented two problems "for clearing the observed distance of the moon from a star "of the effects of refraction and parallax; one trigonome-"trical, by Mercator's sailing,—the other instrumental, by a "sector having a line of chords on each limb and a moveable "portion of a circle of the same radius, which, if of three

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* Sir J. F. W. Herschel's 'Treatise 'on Astronomy,' 1833, p. 102; 1849, p. 115.

† Discours Préliminaire, 'Voyage 'd'Humboldt et Bonpland.' Quatrième Partie. Tome i., p. 27, ed. 1810.

‡ 27 January, 1773.

§ 7 March, 1773.

"feet, the problem may be solved to ten seconds. If I have "time I will make a model of it, and bring it when I come. "Moreover, I can solve the same problem according to Dathorne's method, by two lines of natural cosines upon a "sliding rule." "I like your astronomical instrument," is the immediate reply;*—"All the problems of astronomy "and of sailing might be sufficiently well solved, especially "the last, and I have often wondered such instruments were "not in use. Harrison's watch begins to make a great noise "again. The King has had it tried under his own inspection, "with vast success. Sooner or later it will eradicate astronomy from navigation, which is unlucky for your inventions:" and, some months later,† "As to the quadrant, if it "is intended only to perform tolerably, and to be portable, "it is good; but you do not mean, I suppose, to rank it with "quadrants of some other forms. And how do you intend to "keep the parts of it in the same, or in parallel planes, and "to contrive that your line of chords should constantly be "the base of an isosceles triangle? This last is not very "difficult; but the other, I fear, is. Then you must have a "faithful table of chords, which is still to be formed; for the "published ones are not correct."

Two new barometers contrived by Dr. Small he thus describes:—"In one of my barometers the scale floats within "the tube, and is of such specific gravity, and of so accurately expansile matter, that it constantly shows the weight "of the atmosphere correctly. This is difficult to be made. "The other is very easy. The bason is large; a float of "metal, with a hole for the tube in its middle, lies upon the "surface; a scale stands upon the float, and expands and "contracts just as much as mercury. You can easily imagine "how both may be rendered portable:"—on which Mr. Watt's brief commentary is:—"I admire your expansile "scale, the idea of which I had before, but had none of the "possibility, as I know nothing that expands so much by

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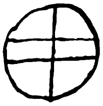
* 15 March, 1773. † 16 October, 1773.

"heat as quicksilver, unless Newton's metal does it. I have "objections to the floating, which I defer to meeting."

In Mr. Watt's survey of the Tarbert and Crinan lines, for a navigable canal, in 1771, he used the micrometer for measuring distances, which he had then invented; and of which, as well as of the circumstances which led to his employment and improvement of it, he has left the following account.

Micrometer for measuring Distances.

"This instrument was contrived about the year 1770 or "1771. I know I used it in the surveys of the Crinan and "Gilp and the Tarbert intended canals, and also in the "survey of the canal from Inverness to Fort William, now "called the Caledonian Canal. The former survey was in "1772,* and the latter in 1773, and it was in 1772 I showed "it to Mr. Smeaton.



"The instrument I used was a telescope with an object-"glass of twelve inches and an eye-glass of one and a half "inch focus; consequently magnifying eight times. In the "focus of the eye-glass there were placed two horizontal "hairs, (see margin,) and one perpendicular hair. "The horizontal hairs were about one-tenth of "an inch distant from each other, and as strictly "parallel to each other and at right angles to "the perpendicular hair as I could make them. A rod being "placed upright at twenty chains distant, or any other con-"venient distance, on level ground, an index consisting of a "round disk of about eight inches diameter painted white, "with a horizontal line of one inch wide painted on its hori-"zontal diameter with vermilion, was fixed upon the rod "about one foot from the ground, and another similar index "was moved up and down the rod, until upon looking through "the telescope the two horizontal hairs covered the red stripes "on the lower and upper indexes, the telescope being turned

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* This date, as has been mentioned, is that of the completion of the Report; the actual survey took place in 1771.

" on its axis until the perpendicular hair was parallel to the " rod. The indexes being thus covered by the horizontal " hairs accurately, the upper index was fixed to the rod, and " the distance between the middle of the red stripes on the " two indexes was divided upon the rod into twenty parts, " representing so many chains, which with the instrument I " used were upon the rod about four and a half inches each, " and for distances exceeding five chains this division into " equal parts was sufficiently accurate; but for shorter dis- " tances it is not strictly so. I therefore fixed a pin at every " chain, and holding up the rod at each of them made the " necessary correction, and as the focus of the object-glass is " also affected by the distance, it is proper to adjust the eye- " glass to it at each station.

" The divisions on the rod being marked with the number " of chains they represent, it was only necessary to send an " assistant with the rod to any place the distance of which " was wanted to be measured, and, by signs, to make him " move the upper index up and down until the two hori- " zontal hairs covered the red stripes on the upper and lower " indexes; the divisions on the rod then showed the distance, " which I found could be ascertained to within less than one- " hundredth part of the whole distance, and with a higher " magnifying power could be done proportionally more accu- " rate. The rod I commonly used was twelve feet long, and " consequently could measure thirty chains; but by sliding " another rod upon it so as to lengthen it, I measured greater " distances; and when still greater were wanted, I stretched " a tape horizontally, and, turning the telescope on its axis, " made the single hair parallel to it, fixing one index at the " end of the tape, and sliding the other along it until it sub- " tended the distance between the wires. I then measured " the subtended tape with the rod, and so ascertained the " distance; but this expedient I rarely had recourse to, the " distances I generally had occasion to measure rarely exceed- " ing half a mile, or forty chains.

" It is plain that this instrument possesses the advantage " of measuring all distances with equal accuracy, until the

" imperfection of vision at great distances interferes, as the
" scale on which they are measured expands with the dis-
" tances; and in uneven ground it possesses more accuracy
" than the chain, and is very valuable in measuring distances
" from one hill to another, and across bays of the sea, where
" the chain cannot be used. This I experienced in the survey
" of West Loch Tarbert, the northern shore of which is very
" much indented, and so rocky that it is scarcely possible to
" measure a few chains in a straight line upon it.

" I showed the instrument to all my friends at the time,
" and, among others, to Mr. Smeaton, as I have mentioned;
" and used it publicly in my surveys, and it was consequently
" known to many people, though not published in print. A
" Mr. Green, in 1778, applied to the Society of Arts for a
" premium for the same invention, which Mr. Smeaton
" apprised me of, and also informed the Society of my
" claims; in consequence of which I was desired to attend
" their committee, where I informed them of what I had
" done, and at what time. Yet the Society thought fit to
" award Mr. Green the premium, though his invention or use
" of the method was posterior to mine,—I suppose because
" he had used an instrument of higher magnifying power, viz.
" forty, and consequently had been able to measure greater
" distances, and, as was said, with greater accuracy. I made
" no further reclamation, as I perceived it was not in that
" court I could obtain justice; and, as I abhor paper war, I
" did not apply to any other, though there were people then
" living who could have attested my use of it.

" Another micrometer, with a prism, I invented, I think,
" about that time. It consisted of
" a thin prism almost parallel (say
" of one degree or two). This prism
" was cut by a diamond into two
" parts, which, when they were fixed
" in the same plane, refracted all the rays which passed
" through them equally; but one of them remaining fixed,
" and the other moving on a centre at *a* (according to the
" pricked line), would refract that portion of the rays which

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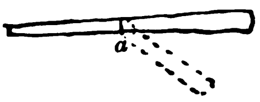
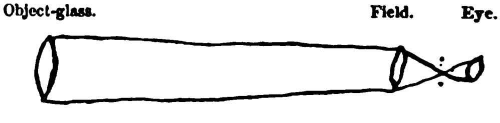


"passed through it more than those which passed through "the fixed part; and being fixed in the focus of the object-"glass of a telescope, two images were formed of each object, "by which its diameter could be measured. An index and "divided sector of a circle served to measure the comparative "refractions. This instrument I made with the sector and "radius of wood, and gave it to Professor Anderson, of "Glasgow College, and I suppose it is still among his appa-"ratus, which he left to a public institution. The Abbé "Rochon afterwards (1783) published a description of some "micrometers with prisms, but I think they were upon some-"what different principles in their construction.

"The cross-hair micrometer, as described, leaving me too "much in the power of my assistants, where the distances "were greater than permitted me to read off the number of "chains on the rod myself, I set about another about 1772 or "1773, which consisted of a telescope with an object-glass of "a long focus, say three or four feet: this was placed in a "tube with a slit in one side of it nearly as long as the focus "of the telescope, and the object-glass being fitted to a short "tube which slid from end to end of the slit, could be moved "backwards and forwards by means of a piece of metal fixed "to the short tube and coming out through the slit: a glass "of six to nine inches focus was also fixed in the outer tube, "in the nature of what is called a field-glass, and to this was "added an eye-glass with a cross-hair piece in its focus; "thus—



"Now it is evident that if the object-glass be moved nearer "the field-glass, their common focus will be shortened, and "the image at the cross-hairs diminished, proportionably, "until, when the glasses come into contact, their common "focus will be shorter than that of the field-glass alone; and "two indexes fixed upon a rod being subtended by the cross-

"hairs at any given distance, the same rod with its indexes being removed nearer the observer, upon sliding the object-glass nearer the eye they may again be subtended by the cross-hairs; a scale on the side of the tube will show the comparative distance they have been removed, and the distance of the first being known, that of the second will also be so. This scale would not, however, be a scale of equal parts, but one which could easily be laid down.

"I made a rough model of this instrument at the time, but have never completed it, having been mostly since in a line of business where such instruments were unnecessary. I described it, however, to several of my friends at the time, and among others to the late Mr. Ramsden; but whether it has been thought of by any one else, or the problem published, I am ignorant."

Sir David Brewster, at a later period, but without any knowledge of the instruments which had been thus contrived by Mr. Watt, invented an improved micrometer with a moveable object-glass, which is described in his 'Treatise on New Philosophical Instruments in the Arts and Sciences, with Experiments on Light and Colours.'* But in a review of that work in the 'Bulletin de la Société Philomathique,' for 1814,† M. Arago having pointed out that the invention of a moveable object-glass for separating, optically, a pair of wires fixed in the focus of a telescope, had been made by M. de la Hire more than a century before, as is mentioned in the 'Mémoires de l'Académie des Sciences' for 1701,—"I have since," says Sir David, in writing to Mr. Watt, with the candour by which that eminent philosopher has always been honourably distinguished, "examined M. de la Hire's work, "and find that M. Arago is perfectly correct. This fact "therefore deprives you and me of all original merit in the "invention of the principle, although you were as little "acquainted with De la Hire's labours as I was with yours. "The idea, however, of converting it into a general micrometer, of applying it to the *divided* object-glass (which is "decidedly its best form), and of converting a Gregorian or "Cassigrainian telescope into a micrometer without any additional lens or mirror, is still mine."*

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* Edinburgh, 1813, 8vo.

† "Un instrument entièrement semblable à celui-là avait été employé par Roëmer et Lahyre, comme on peut le voir dans le Recueil de l'Académie des Sciences pour 1701. M. Brewster n'avait sûrement pas connaissance de ces Mémoires, car il propose, dans un autre chapitre de son ouvrage (p. 76), de substituer des fils de verre aux fils métalliques ou d'araignée dont on se sert communément dans le micromètre, et cela sans citer Lahyre, qui avait eu la même idée il y a plus de cent ans; et qui, de plus, avait décrit avec détail les moyens ingénieux dont on se sert pour obtenir ces filamens; ce même astronome paraît aussi s'être occupé le premier des micromètres qu'on peut tracer sur verre avec la pointe d'un diamant.—(Voyez Mémoires de l'Académie, 1701, p. 119 et suivantes.)" 'Bulletin des Sciences par la Société Philomathique de Paris,' année 1814, Paris, p. 35.

In the volume to which M. Arago refers, M. de la Hire mentions ('Mém. de l'Acad. des Sciences' for 1701, p. 128) that, after having composed his memoir, he found, in the History of the Academy, that M. Roëmer had at an earlier date proposed a micrometer for measuring the diameter of stars, with a moveable object-glass. But the idea of making the micrometric lines either concentric circles engraved on glass with a diamond point, or, if rectilineal, of forming them of threads of glass, appears to have originated with M. de la Hire; who, in another memoir, ('Mém. de l'Acad.' for 1717, pp. 57–67), explains certain inconveniences which he experienced from such a micrometer when applied to astronomical purposes, which led him to abandon its use, and to suggest yet another sort, which he then goes on to describe particularly.

In the same volume of the 'Mémoires de l'Académie' to which we have last referred, but in another part of it, there is contained another memoir by the same learned and indefatigable author, in which he says that, having observed that there were often great disputes as to who were the first inventors of the micrometer and of the pendulum clock, he thought it desirable to record the result of his own examination of what had been published on that subject, as well as of the private knowledge he had derived from the opportunities with which a very long experience and his intimacy with elder philosophers had supplied him. He then shows that a micrometer with a fixed *virgula* was employed by Huygens, as stated in his book on the 'System of Saturn,' printed in 1659, to measure the diameter of the planets;—that one with cross silver wires was used by the Marquis Malvasia previous to 1662, in which year that nobleman published his 'Ephemerides;'—that in 1666, MM. Auzout and Picard published their account of a much more exact and convenient instrument nearly of the same kind, in which the silver wires were advantageously exchanged for fine silk threads, or hairs; and he therefore attributes to Huygens the original invention, which had since been progressively brought nearer to perfection.

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* Sir David Brewster to Mr. Watt, December 12, 1816.

M. de la Hire philosophically remarks, that, as almost all that is most curious and useful in science and the arts, whether liberal or mechanical, has not at first been invented such as we now possess it, but has attained to perfection only by slow degrees and the labour of different hands, it is very difficult in such cases duly to apportion the merit of the discovery; and he aptly illustrates his position by the history of the invention of telescopes, in which the first step appears to have been quite an accidental one, while subsequent advances were the result of scientific experiment or theory.

To M. de la Hire's honour it is to be observed, that he took all possible pains to record the contrivance of MM. Auzout and Picard in all its particulars; for their first account of it, contained in a letter from M. Auzout to Mr. Oldenburg, Secretary to the Royal Society of London, which was printed in a separate form in 1667, but had become extremely rare and difficult to be procured, may fairly be said to owe its preservation principally to him. He included it in a collection of treatises on various subjects in mathematics, astronomy, and natural philosophy, by different academicians, which was printed in 1693, under his own care. That edition of the Collection was in two volumes folio, but it was soon afterwards reprinted in quarto, in which form it is probably better known, or is at least more accessible to most of our readers, being a portion of that series of the 'Mémoires de 'l'Académie' which extends from 1666 to 1699. There the paper in question, with an illustrative engraving, will be found at pp. 113–130 of the first part of the seventh volume.

But, after having thus done justice to other countries in recording the share which they took in the invention of the micrometer, it is satisfactory to be able to prove on undoubted authority that ultimately the priority in that invention, so highly beneficial to astronomical science, and "the applica-"tion of which first gave to more exact graduation its pecu-"liar and indeed inestimable value,"* must be awarded to England. Sir John F. W. Herschel,—the illustrious son of an illustrious sire,—has well pointed out that "the honour of "this capital improvement has been successfully vindicated "by Derham ('Phil. Trans.' xxx. 603) to our young, talented, "and unfortunate countryman Gascoigne, from his corre-"spondence with Crabtree and Horrockes, in his (Derham's) "possession. The passages cited by Derham from these "letters leave no doubt that, so early as 1640, Gascoigne "had applied telescopes to his quadrants and sextants, *with* "*threads in the common focus of the glasses*, and had even "carried the invention so far as to illuminate the field of "view by artificial light, which he found 'very helpful when "'the moon appeareth not, or it is not otherwise light "'enough.' These inventions were freely communicated by "him to Crabtree, and through him to his friend Horrockes, "the pride and boast of British astronomy; both of whom "expressed their unbounded admiration of this and many "other of his delicate and admirable improvements in the art "of observation. Gascoigne, however, perished, at the age "of twenty-three, at the battle of Marston Moor; and the "premature and sudden death of Horrockes, at a yet earlier "age, will account for the temporary oblivion of the inven-"tion. It was revived, or re-invented, in 1667, by Picard "and Auzout (Lalande, 'Astron.' 2310), after which its use "became universal. Morin, even earlier than Gascoigne, (in "1635), had proposed to substitute the telescope for plain

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* Humboldt's 'Cosmos,' vol. iii. part i. p. 44, ed. 1851.

"sights; but it is the thread or wire stretched in the focus, "with which the image of a star can be brought to exact "coincidence, which gives the telescope its advantage in "practice; and the idea of this does not seem to have occurred to Morin. (See Lalande, *ubi supra.*)" *

For a summary of the dispute as to the invention of *prismatic* micrometers, we may refer our readers to M. Mathieu's learned note on Delambre ('Histoire de l'Astronomie au dix-huitième Siècle,' pp. 645-652, ed. 1827). There the priority is attributed to Rochon, who presented the Academy of Sciences with a description and a specimen of that sort of instrument in January and February, 1777, and in April following reported to the same learned body the measurements of Mars, of Jupiter, and of Saturn with his ring, which he had obtained by its aid.

Maskelyne, who, in December 1777, presented his prismatic micrometer to the Royal Society, produced an attestation by Dollond that he had constructed it for him in the previous year, and taken it to the Observatory at Greenwich in August, 1776.†

To both of those dates Mr. Watt's invention appears to have been antecedent by several years; although of it we may say, as M. Mathieu has done of that of Rochon, "Cet "ingénieux instrument ne reçut pas, dans le temps, tout "l'accueil qu'il méritait."

"The Abbés Boscovich, Fontana, Rochon, Maskelyne," wrote Dr. Patrick Wilson‡ to Mr. Watt, in 1778, "are a very

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* Sir J. F. W. Herschel's 'Treatise 'on Astronomy,' ed. 1833, p. 86; ed. 1849, p. 92, *note*. See also Humboldt's 'Cosmos,' vol. iii. part i., pp. 44, 59, 64, and 96, ed. 1851.

† See the 'Philosophical Transac'tions' for 1777, vol. lxvii. pp. 799-813, &c. See also Boscovich's 'Account 'of a new Micrometer and Megame'ter,' *ibidem*, pp. 789-798.

‡ Dr. Patrick Wilson was the second son of Dr. Alexander Wilson, celebrated not only for his accurate and ingenious observations on the solar spots, but also for having introduced a new era in the art of type-founding in this country: (see Humboldt's 'Cosmos,' vol. iii. pp. 273 and xcvi; 'Phil. Trans.' for 1774, vol. lxiv. pp. 6-13; Preface to the Foulis Homer, vol. i. p. viii; and the interesting biographical memoir published in Brewster's 'Edinburgh Jour'nal of Science' for Jan. 1829, pp. 1-17.) The son shared largely in all his father's pursuits, and in 1786 became his successor in the astronomical professorship at Glasgow. His aptness for philosophical experiments was made favourably known by his

“creditable junto of philosophers, who are at present drawing some attention as inventors of a prismatic micrometer. My father and I feel a wish of seeing your name added to that band of improvers. Your invention, though very little known, was several years prior to any of theirs. If you choose to assert this priority by any publication, it will give us great pleasure to contribute our evidence in your favour;”—and, to the same effect, and at the same time, Dr. W. Irvine:—“Pray have you seen the last volume of the Transactions? You must surely know that it contains the description of a certain micrometer, that shall be nameless, made by one J. Watt six or eight years ago, and which has been in Macfarlane's Observatory in Glasgow for several years past. Would you not think it proper that the said J. Watt should claim this discovery? And as the authors of these papers in the Transactions have brought witnesses, he might bring Dr. Reid, Dr. Wilson, Pat. Wilson, G. Hamilton, &c., who are ready and willing to attest the same, and who are surely as respectable as Pat. Dollond and —— Aubert;

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paper in the 'Phil. Trans.' for 1781 (vol. lxx. p. 451), entitled 'An Account of a most Extraordinary Degree of Cold at Glasgow in January last; together with some New Experiments and Observations on the Comparative Temperature of Hoar-frost and the Air near to it, made at the Macfarlane Observatory belonging to the College;' together with 'Further Experiments on Cold,' &c. (Phil. Trans., vol. lxxi. p. 386); and 'Experiments and Observations on a remarkable Cold which accompanies the separation of Hoar-frost from a clear Air' (Trans. of the Royal Society of Edinburgh for 1788, vol. i., p. 146), as well as by his paper, also published in the 'Phil. Trans.' (for 1782, vol. lxxii. p. 58), proposing an 'Experiment for determining, by the Aberration of the Fixed Stars, whether the Rays of Light, in pervading different media, change their Velocity according to the law which results from Sir Isaac Newton's ideas concerning the cause of Refraction, and for ascertaining their Velocity in every medium whose refractive density is known.' Having in 1799 resigned the chair of Practical Astronomy in order to reside near London, in the society of the Herschels and other friends distinguished in pursuits congenial to his own, he on that occasion, “as a mark of his high regard” for the learned body “so long and so intimately known to him, and in testimony also of his desire for the future prosperity of the office of Professor of Practical Astronomy in the said College, which was first filled by his ever-honoured father,” endowed the University of Glasgow with a fund of considerable amount, for the purpose of purchasing astronomical books and apparatus, as well as of bestowing occasionally a gold prize medal on meritorious students of his favourite science. Dr. Patrick Wilson died at Kensington, 31st December, 1811. (See 'Deeds instituting Bursaries, Scholarships, and other Foundations in the College and University of Glasgow.' Privately printed for the University. 1850. pp. 253-258.)

"and to make the whole still stronger, I should imagine you "could have no objection to join in the attestation. You "may perhaps despise such unprofitable inventions; but to "others they will procure fame, and perhaps fortune."

One other "gimcrack," and we have done with the long list of useful and ingenious contrivances with which it had been the pleasure of the great engineer, up to this period, to occupy his few hours of leisure;—"I have invented a drawing-machine," he says,* "the board horizontal, the index "almost as long as you please, and consequently the size of "the picture large; a telescopic sight; no specula; the "whole being performed by a most simple joint. When the "index does not exceed two feet long, the instrument and "apparatus consist of a box 14 inches long, 1¼ deep, and 4½ "inches broad, which opened is the drawing-board, and contains the apparatus, except a light wooden tripod head for "the pocket, and a staff for the hand, of the ordinary size. "By help of this machine I can draw from an eminence a "draught of level grounds that shall be a true projection of "them, and shall measure by a scale of equal parts. It also "draws all kinds of perspective draughts, reduces maps, &c., "the board being always horizontal, whether the objects be "vertical or not."

Within a fortnight, however, came this reversal of the verdict thus pronounced:—"I caused to be made a part of "the machine I mentioned in my last; it has only one fault, "which is, that it will not do, because it describes conic "sections instead of right lines;"† and although there can be no doubt that by a little further labour on the part of the inventor this difficulty would have been overcome, yet events of more importance soon occurred, which seem to have put a stop to the career of "gimcracks," in which he and his friend Small had so long and cheerfully been running a race together, and which led the latter to remark to his friend,—"You might live by inventing only an hour in a "week for mathematical-instrument-makers."

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* To Dr. Small, 11 December, 1773.

† 24 December, 1773.

The termination of Mr. Watt's labours as a civil engineer was an abrupt one, accompanied—and indeed in some measure caused—by a melancholy event. Having been suddenly recalled from his survey of the Caledonian Canal in the autumn of 1773 by the intelligence of the dangerous illness of his wife, he had the deep grief of finding on his return home that she had died, after having given birth to a still-born child. Mrs. Watt is described as having been a very amiable person, whose gentle counsels and uniform good temper had often sustained her husband's hopes and animated his exertions, under the depressing circumstances of indifferent health, narrow means, and variable and often desponding spirits; from all of which he then suffered in no ordinary degree. By relieving his mind as far as possible of other care, and thus affording it the undisturbed leisure required for study and exertion in his various pursuits, she might even be said to have been of material, though, of course, subsidiary service to him in the progress of his great invention. She earnestly encouraged the hopes which he founded upon it; and even when these seemed for a time to be quite overthrown, her buoyant spirits did not sink, nor did her cheerful faith fail; but she wrote to him with truly feminine fortitude, —"I beg you would not make yourself uneasy, though things "should not succeed to your wish. *If it*" [the new steam-engine] "*will not do, something else will. Never despair.*"[*]

"The few years," says Miss Campbell, "of his union with "Miss Miller passed in uninterrupted domestic happiness. Of "her untimely death, and the beautiful composure of mind, "and affecting tenderness for her husband and children, that "she displayed in her last moments, my mother never could "speak without tears."

The agony of grief which he suffered on losing so judicious, so beloved, and so faithful a friend, sufficiently appears from those of his letters of that date which have been preserved; although some others, it is to be regretted, appear to have been lost or destroyed, probably in consequence of containing no allusion to anything but his private sorrow. Of one, which survives only in the form of an undated fragment, addressed to Dr. Small, but evidently belonging to the period in question, the expressions are gloomy indeed;—more so, happily, than the habitual resignation of its writer to the will of the Supreme Disposer of all events seems ever to have permitted him to repeat. " Let us," he writes, " rejoice in our youth, " for age is dark and unlovely, and in the silent grave there " is no joy, at least that we know of;—vive, et vale." And again:—" You are happy, Small, that have no such con" nection. Yet this misfortune might have fallen upon me " when I had less ability to bear it, and my poor children " might have been left suppliants to the mercy of the wide " world. I know that grief has its period; but I have much " to suffer first. I grieve for myself, not for my friend; for " if probity, charity, and duty to her family can entitle her " to a better state, she enjoys it. I am left to mourn. * * " Let me leave this tale of woe."

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[*] August 9, 1768.

" Would that I might here transcribe," said Arago, " in all " their simple beauty, some lines of the journal in which he " daily recorded his inmost thoughts, his fears, his hopes! " Would that you could see him, after this heavy affliction, " pausing on the threshold of that home, where 'HIS KIND " 'WELCOMER' awaited him no more; unable to summon " courage to enter those rooms, where he was never more to " meet 'THE COMFORT OF HIS LIFE!' "

Of the four children who were the issue of Mr. Watt's marriage with Miss Miller, two died in infancy; one daughter married a Mr. Miller of Glasgow, but died early, leaving issue a son and two daughters, (now all dead, the daughters having left issue); and the only son of that family who attained manhood was the late Mr. James Watt, of Aston Hall, who long survived his father as his respected representative, and died, unmarried, in 1848.

CHAPTER XVII.

DEPRESSION OF SPIRITS — INSOLVENCY OF DR. ROEBUCK — FORMATI
PARTNERSHIP WITH MR. BOULTON — TRANSFERENCE OF THE EN
GINE TO SOHO — PROLONGATION OF PATENT OF 1769 — DEATH
SMALL — NOTICES OF HIS LIFE, TALENTS, AND VIRTUES — P
AND PROSPECTS OF THE NEW MANUFACTORY — ARTICLES OF
NERSHIP.

THIS last most grievous calamity put the finishing st
the long series of adverse circumstances by whic
had been oppressed. For years previously he h
plained of frequent violent headaches, and almost
bad health; of what he called laziness, stupefaction,
fusion of ideas, which no doubt meant the mental
arising from severe and anxious over-exertion; of th
ness of the employment of land-surveying, to whic
then become a slave; of his detestation of making
or settling accounts, or forcing workmen to do thei
that "I greatly doubt," he says in 1770, "whether
" mansions of the grave be not the happiest abodes.'
" heart-sick of this country," he writes, after the
wife, to his sympathising friend Dr. Small, "I an
" to excess, and, what alarms me most, I grow the
" stupider. My memory fails me so as often totall
" occurrences of no very ancient dates. I see m
" demned to a life of business; nothing can be mor
" able to me; I tremble when I hear the name o
" have any transactions to settle with. The e
" business is not a vigorous plant here; we are
" very poorly paid. This last year my whole ga
" exceed 200*l.*, though some people have paid me
" teelly. There are also many disagreeable circu
" cannot write; in short I must, as far as I see, c
" abode. There are two things which occur to me

"try England, or endeavour to get some lucrative place "abroad; but I doubt my interest for the latter. What I "am fittest for is a surveying engineer. Is there any business "in that way?" And, about the same time, it appears that Dr. Roebuck had mentioned Mr. Watt having had an intention of passing the winter in France; to escape, doubtless, from the sorrowful associations that now pressed upon him in his own country.

These circumstances all concurred with the disastrous state of affairs at Borrowstoness and Kinneil, to hasten the final settlement of the agreement with Mr. Boulton and Dr. Small. But it was now evident, since Roebuck had become insolvent, and therefore unable to be any longer a partner in the proposed manufacture, that instead of one-half of his two-thirds of the patent of the engine, or one-third of the whole patent, as originally intended when that agreement was entered into in 1769, the whole of his interest would have to be purchased from him or his creditors. We have already seen that Boulton and Small were not more desirous of benefiting Watt, than Watt was of benefiting Roebuck; and also, that although all four were anxious to see the engine prosecuted to completion, and its merits tested by actual performance on a great scale, none of them, (and, least of all, the inventor), estimated the invention, as then attempted to be carried out, as of any very high pecuniary value. In this view, it fortunately happened, that Roebuck's creditors most fully concurred; "none of his creditors," writes Watt to Small,* "value the engine at a farthing;" and this uncomplimentary estimate,—at which we now so well may marvel, and the creditors might soon afterwards have mourned,—was really of the greatest service in hastening the progress of the transference of the property.

On terms satisfactory at the time to Dr. Roebuck, and which consisted in part at least of Mr. Boulton releasing him from a debt of 630*l.* due to him by the Doctor, and of the payment by Mr. Boulton of a further sum of 1000*l.*, this transference at last took place, to Mr. Boulton alone; Dr. Small having by that time otherwise engaged all of his available funds. The 1000*l.* paid were to be the first 1000*l.* of profit, (without repayment of any already sunk), that might arise after the commencement of the partnership of Boulton and Watt. And in 1773 Mr. Watt and Dr. Roebuck executed a mutual discharge, which, as an interesting document in the history of the modern steam-engine, we shall here give entire:—

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* 25 July, 1773.

"In the year 1767, Doctor John Roebuck at Kinn
" entered into partnership with James Watt at Glasgow,
" verify and carry into practice an improved fire-eng
" invented by the said James Watt. Doctor Roebuck wa
" pay a debt of 1000*l.* incurred by the said James Watt
" making the experiments tending to the invention of
" engine, and also to pay the expense of the patent
" further experiments.

"James Watt was to attend and conduct the experime
" and assigned to the Doctor two-thirds of the property of
" said invention, retaining one-third for his own use.

"Dr. Roebuck has paid the thousand pounds, but
" expense of the other things has been principally paid
" James Watt.

"In consideration of the mutual friendship subsis
" between Dr. Roebuck and myself, and because I think
" thousand pounds he has paid more than the value of
" property of the two-thirds of the inventions, I hereby
" upon myself all other sums I have laid out or paid up
" also all other debts I have contracted upon that
" relieving the Doctor from the same, and meaning th
" an absolute discharge for all sums he may have been
" me before this date.

"Kinneil, May 17th, 1773." "JAMES WA

"Having examined the above narration of facts, I ac
" lodge the same to be just, and hereby discharg
" account.

"Kinneil, May 17, 1773." "JOHN ROEBU

Thus, in the summer of 1773, Mr. Watt found himself at liberty to remove from Kinneil, where they had long been lying useless, and "perishing" from "long exposure to the "injuries of the weather," the iron works, cylinder, and pump, of the condensing engine partly erected there three years before. Those "disjecta membra" were then packed up and sent off to Soho, where a boiler was awaiting them, destined to inspire them with new life and movement; but it was not till after another year that they were followed by Mr. Watt, who had in the interval made his survey for the Caledonian Canal, and had suffered the loss, in which it so dismally terminated, of his much-loved wife.

Early in April 1774, he writes to Dr. Small, "I begin "now to see daylight through the affairs that have detained "me so long, and think of setting out for you in a fortnight "at furthest;"—and, early in May, "I have persuaded my "friend Dr. Hutton, the famous fossil philosopher, to make "the jaunt with me, and there are some hopes of Dr. Black's "coming also." The next four or five months were passed in continuous though still partially futile attempts to construct a satisfactory wheel-engine, and in more successful ones to make the condensing engine do some good work. By the end of October, Mr. Watt was able to send his friend Roebuck such a report of the latter, that Dr. R. replied,* "You have "now effectually established the justness of the principles on "which your machine is constructed, and the generous and "spirited gentleman you are connected with will never suffer "it to fail for want of exertion to carry it into execution." He was also able to cheer the heart of his aged father, in his lonely home at Greenock, by writing to him, from Birmingham,† "the business I am here about has turned out rather "successful, that is to say, that the fire-engine I have invented "is now going, and answers much better than any other that "has yet been made; and I expect that the invention will be "very beneficial to me."

The comfortable results which led to these improved hopes, had been obtained, it must be recollected, with a cylin made at Carron so far back as 1766, and not very tr bored, although the best which that manufactory could tu out at that time; and Carron had the best boring-mill, cannon and the cylinders of the old sort of steam-engi then known. “It was only intended,” says Mr. Farey, “ “boring cannon; but they bored barrels [of pumps] “cylinders [for atmospheric engines] by it occasionally. “the course of a few years, this mill proved too small “execute the work which their trade required, and in 1 “Mr. Smeaton made them an entire new boring-mill “guns, and another for cylinders.” *

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* 12 November, 1774.

† 11 December, 1774.

But Mr. Boulton, encouraged by the favourable re already obtained, applied, early in 1775, for a better cylin to Mr. John Wilkinson, an eminent iron-founder at Bers near Chester, who at that very time, probably in consequ of the great demand he saw reason to believe would aris cylinders bored with exact truth throughout, introduc new boring-machine which was an infinite improvemen the old one. “In the old method,” says the same accu author whom we have last quoted, “the borer for cutting “metal was not guided in its progress, and therefore foll “the incorrect form given to the cylinder in casting it “was scarcely insured that every part of the cylinder sh “be circular; and there was no certainty that the cyli “would be straight. This method was thought sufficien “old engines, but Mr. Watt's engines required gr “precision.

“Mr. Wilkinson's machine, which is now the com “boring-machine, has a straight central bar of great stre “which occupies the central axis of the cylinder, during “operation of boring; and the borer, or cutting instrum “is accurately fitted to slide along this bar, which, b “made perfectly straight, serves as a sort of ruler, to g “rectilinear direction to the borer in its progress, so “produce a cylinder equally straight in the length, and

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* Farey, Treatise on the Steam-engine,' 1827, p. 291.

cular in the circumference. This method insures all the accuracy the subject is capable of; for, if the cylinder is cast ever so crooked, the machines will bore it straight and true, provided there is metal enough to form the required cylinder, by cutting away the superfluities."*

But, notwithstanding the improved cylinder, and those ther aids of mechanism which could then be derived from he workshops of Soho and Birmingham, it was very evident hat a long series of experimental trials was still requisite efore the engine could be brought to such perfection as to ender it universally available to the public, and, therefore, rofitable to its manufacturers. In January 1775, six years f the period named in the Letters Patent had already xpired; and there seemed every probability of the eight hat remained proving only sufficient to admit of a great utlay of labour, talent, and money, for the benefit of others who had exerted no ingenuity, incurred no risk, and displayed no perseverance.

The eminent counsel whom Mr. Watt consulted, suggested the surrendering up of the patent, and did not doubt that a new one would then be issued, granting the exclusive privilege anew from its date. Other friends recommended that an application should be made for an Act of Parliament extending the time allowed by the first patent, and this was the course which it was finally determined should be taken. The application met, rather unexpectedly, with very strong opposition, to which the great oratorical powers of "the "immortal Burke" gave a dangerous importance. He, it is believed, was influenced by what he conceived to be, or what were represented to him to be, the claims of a constituent, and not by any more unworthy feeling of hostility to either Mr. Watt or his patent; but nevertheless he was led to support with all the power of his great name what he probably would afterwards have confessed to be a measure of gross injustice. Happily, the eloquence of himself, and the influence of his associates, failed of their intended effect; and, on the 8th of May, 1775, Mr. Watt had the pleasure of being able to write to his father, from London, the following letter:—

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* Farey, p. 326.

"Dear Father,—After a series of various and violent opposition, I have at last got an Act of Parliament vesting the property of my new fire-engines in me and my assigns, throughout Great Britain and the Plantations, for twenty-five years to come, which I hope will be very beneficial to me, as there is already considerable demand for them.

"This affair has been attended with great expense and anxiety, and without many friends of great interest I should never have been able to carry it through, as many of the most powerful people in the House of Commons opposed it. It has been in Parliament ever since the 22nd of February, which is a very long time to be kept in suspense.

"I shall be obliged to stay here a few days longer, after which I return to Birmingham to set about making some engines that are ordered; after which I intend to give myself the happiness of seeing you and the dear children. * * My warmest wishes and affection ever attend you; may God render your age comfortable is the prayer of your ever affectionate and dutiful son, JAMES WATT."

But while this affair was pending, and Mr. Watt was absent in London attending to it, another heavy blow had fallen upon him. This was, the death of Dr. Small; the faithful and affectionate friend who had so long encouraged him in despondency, consoled him in misfortune, and aided him in attaining to the comparative prosperity which was now at last beginning to dawn upon him. "The last scene," feelingly writes Mr. Boulton to him in London,* "is just closed; the curtain is fallen, and I have this evening bid adieu to our once good and virtuous friend, for ever and for ever. If there were not a few other objects yet remaining for me to settle my affections upon, I should wish also to take up my lodgings in the mansions of the dead." "To pretend to offer you consolation," is Mr. Watt's reply, "under the weight of your present sorrow, I know to be in vain. I

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* [25 February, 1775.]

" only beg leave to repeat to you the sentiments which that " dear friend we lament expressed to me upon a similar occa- " sion. It is our duty as soon as possible to drive from our " minds every idea that gives us pain, particularly in cases " like this, where our grief can avail nothing. Remember, " my dear Sir, that our friend enjoys that repose he so much " desired; and we ought not to be so selfish as to render our- " selves unhappy by the perpetual recollection of our own " misfortune, however great we may think it, for it is also " irreparable and was inevitable." * * " Come, my dear " Sir, and immerse yourself in this sea of business as soon as " possible, and do not add to the griefs of your friends by " giving way to the tide of sorrow. I again repeat that it is " your duty to cheer up your mind and to pay a proper " respect to your friend by obeying his precepts. I wait for " you with impatience, and assure yourself no endeavour of " mine shall be wanting to render life agreeable to you." " We have lost a most valuable friend," writes Dr. Roebuck on the same occasion, " a gentleman of extensive knowledge " and learning."

Of Dr. William Small, whose family name is, perhaps, best known in the annals of science by his brother Dr. Robert Small's learned 'Account of the Astronomical Discoveries of 'Kepler,' we have few particulars to record beyond those which his correspondence with Mr. Watt supplies. But his early death has been commemorated and lamented by the pens of Keir, of Day, and of Darwin; and all the scattered notices that we have been able to collect attest the greatness of his talents and his worth. A native of Scotland, he was born in 1734 at Carmylie in the county of Angus, of which parish his father was minister; one of his ancestors being Mr. Thomas Small of Corrihall, whose armorial bearings were registered in the Lyon Office about 1680. Having been appointed Professor of mathematics and natural philosophy in the college of Williamsburgh in Virginia, he settled there for some years, and practised with great success as a physician; but coming home on account of his health and some business, he " preferred settling at home to returning to Virginia, as he "never kept his health there." He was introduced to Mr. Boulton in 1765,—(the year, we need scarcely repeat, in which Mr. Watt made his memorable discovery of the separate condenser),—by a letter from no less eminent a person than Benjamin Franklin; in which he is described as "one who "is both an ingenious philosopher, and a most worthy, honest "man;" and Lord Brougham has mentioned that he was the instructor in mathematics of the celebrated Thomas Jefferson.* "He is," adds another of his friends in writing from London to Mr. Boulton, to announce his arrival in England, "a "gentleman of great worth, integrity, and honour; and in "the way of his profession he has the best recommendations "of our most eminent physicians here." To the same effect is Mr. Keir's account of him, as "a gentleman of very un-"common merit," possessed of singular accuracy of ideas, and great acquaintance with men and things; "who, to the "most extensive, various, and accurate knowledge in the "sciences, in literature, and in life, joined engaging manners, "a most exact conduct, a liberality of sentiment, and an "enlightened humanity; being a great master in the exact "sciences, and seeming to carry their regularity and precision "into his reasonings and opinions on all other subjects."† And in a MS. note on our copy of the work from which our last quotation is taken, and which was presented by its author to Mr. Seward, its former possessor has added:—"He "had, I think, the greatest variety, as well as the greatest "accuracy of knowledge, that I have ever met with in any "one man."

It does not exactly appear whether Mr. Watt had ever met him previous to their acquaintance at Birmingham and Soho in 1767; but in age they were nearly coevals, and their correspondence shows how entire was their community of sentiment, and how similar the course of their favourite pursuits.

The happy companionship of which Mr. Watt's new association opened up a prospect to those congenial spirits, was, alas! but too evanescent. In many of Dr. Small's letters he complains of feelings of languor and melancholy, which betokened an undue failure of vigorous health: "*nil admirari*," says Mr. Keir, "was his favourite motto; which, however, he "afterwards, as his health and spirits declined, changed to "one of a darker cast, μὴ φῦναι, the two first words of a line "of Euripides,* expressing that it would have been better "not to have been born." "The *ennui mortel*," says Dr. S. in 1773, "has totally ruined me for an experimental philo-"sopher. * * I flatter myself that I shall soon be '*pulvis* "'*et umbra*,' and fold my arms to sleep. Who will call me "projector now?" "I am exceedingly happy to find you "talk of coming hither. I shall be preserved one year longer "at least from this lethargy, which must at last compose me "for ever." "In my whole life I have never experienced so "long a fit of languor as I am now in," &c. &c. And the same spring which was to witness the triumphant passing of the Act of Parliament extending the duration of the patent of 1769, beheld the languishing illness and premature death of that able, zealous, and amiable friend, whose exertions had so greatly contributed to the establishment of the Soho steam-engine partnership. Early in 1775 he was seized with the symptoms of an ague to which he had previously been subject, and which did not at first appear to threaten an illness of more than common severity; but the disease proved to be a continued fever, which, notwithstanding every aid of medical skill, terminated fatally. He died on the 25th of February, having remained sensible to the

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* Lord Brougham's Lives of Statesmen, vol. ii. Series III., p. 53, ed. 1845.

† Keir's 'Account of the Life and 'Writings of Thomas Day, Esq.,' 1791, p. 111, *note*.

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* Not from the celebrated speech of Jason in the Medea—

> "Δεῖ μ' ὡς ἔοικε, μὴ κακὸν φῦναι λέγειν,"—
>
> Eur. Med., l. 522.

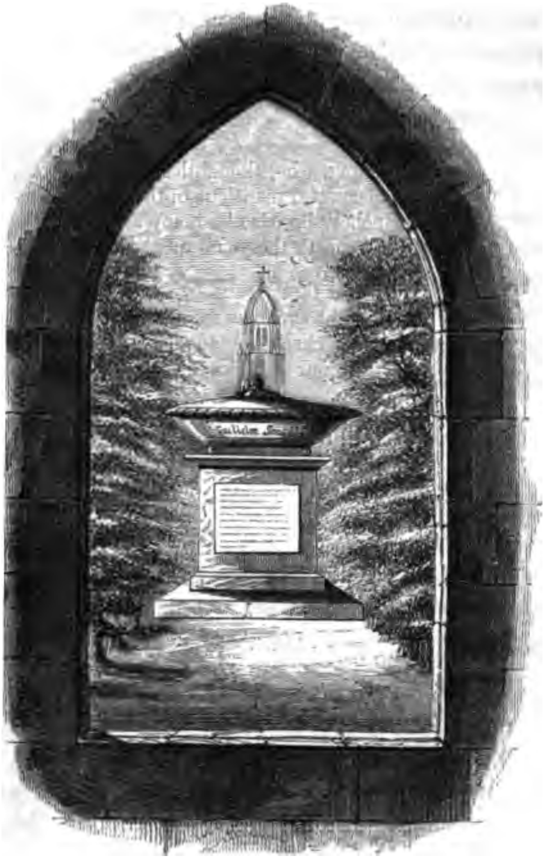
but from one of the fragments of the Bellerophon—

> "'Εγὼ τὸ μὲν δὴ πανταχοῦ θρυλλούμενον
> "Κράτιστον εἶναι φημι, μὴ φῦναι βροτῷ."
>
> Eur. Fragm. Belleroph., xvi. 2; vol. ii. p. 432, ed. Lips., 1779.

It will be seen that Mr. Keir, when he placed the words *first* in the line, evidently spoke without referring to his author.

last, and almost to the last having entertained hopes of h
own recovery. At the time of his decease, Mr. Watt was u
avoidably absent, at Broseley in Shropshire, on business co
nected with the engine; but Dr. Ash and Dr. Darwin, wi
both of whom Dr. Small had always lived on terms of t
greatest intimacy, Mr. Boulton, Mr. Keir, and other attac
friends, constantly attended him in his last illness.

Mr. Keir has regretted, to a certain extent not wit
reason, that "Dr. Small, although possessed of various
"eminent talents to instruct mankind, has left no
"behind of all that store of knowledge and observation
"he had acquired, and from which his friends never lef
"without drawing fresh information." But the paneg
not small which he pronounces, when he adds;—"H
"only in the memory of those friends who knew his
"and of the poor, whom his humane skill was ever re
"rescue from disease and pain." "It is needless," wri
same gentleman in announcing his death to his broth
Rev. Robert Small of Dundee, "to say how universall
"lamented; for no man ever enjoyed or deserved m
"esteem of mankind. Mr. Boulton and myself, wh
"more particularly blest with his intimacy and frie
"are struck with a grief suitable to the loss which w
"sustained, and which we know can never be repaire
"loved him with the tenderest affection, and sha
"revere his memory." "His numberless virtues," s
Boulton, "I should be happy to fall heir to, they be
"only legacy that could reconcile me to his death." "
"Keir, Darwin, Day, and self," adds Mr. Boulton at
date, "have never yet agreed about a monument
"church; but as there is nothing which I wish to fix
"mind so permanently as the remembrance of my
"parted friend, I did not delay to erect one to his
"in the prettiest but most obscure part of my garden;
"that is modelled, at least characterised, since you we
"'Tis a sepulchred grove, in which is a building ada
"contemplation; from one of its windows, under a
"arch formed by trees, you see the church in which



" interred,* and no other object whatsoever except the monu-
" ment. It is a sarcophagus standing upon a pedestal, on
" which is written

M : S :
Gulielmi Small, M.D.
Ob. Feb. xxv.
MDCCLXXV.

" and upon the pedestal are inscribed some verses written by
" Dr. Darwin, a copy of which, with a slight sketch of the
" view from one of the windows of the building, I herewith
" send you :—

" Ye gay and young, who, thoughtless of your doom,
" Shun the disgustful mansions of the dead,
" Where Melancholy broods o'er many a tomb
" Mould'ring beneath the yew's unwholesome shade;

" If chance ye enter these sequester'd groves,
" And day's bright sunshine for a while forego,
" O leave to Folly's cheek the laughs and loves,
" And give one hour to philosophic woe!

" Here, while no titled dust, no sainted bone,
" No lover bending over beauty's bier,
" No warrior frowning in historic stone,
" Extorts your praises or requests your tear;

" Cold Contemplation leans her aching head,
" On human woe her steady eye she turns,
" Waves her meek hand, and sighs for Science dead,
" For Science, Virtue, and for SMALL she mourns."

Mr. Day also, who had hastened to England from Brussels as soon as he heard of the severe illness of his friend, (although unfortunately too late to be present with him in his last hour), and whose mind was long in recovering from the gloom caused by the loss of one whom he had always venerated as a wise and faithful instructor, composed the following epitaph on his "guide, philosopher, and friend:"—

" Beyond the rage of Time, or Fortune's power,
" Remain, cold stone! remain, and mark the hour
" When all the noblest gifts which Heaven e'er gave
" Were centred in a dark, untimely grave.

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* That of St. Philip, Birmingham.

"O taught on reason's boldest wings to rise,
"And catch each glimmering of the opening skies!
"O gentle bosom! O unsullied mind!
"O friend to truth, to virtue, and mankind!
"Thy dear remains we trust to this sad shrine,
"Secure to feel no second loss like thine!" *

The "sepulchred grove" of Soho has fallen; the "sarcophagus," — or, rather, *cenotaph*, — has perished; and the romantic grounds surrounding Mr. Boulton's mansion, with their woods and waters, little more than a century ago an unpeopled and uncultured waste, then transformed into a series of smiling gardens and shaded lawns, have now become the site of other houses, multiplying in proportion to the immense development of the steam-engine and its results in that central and busy district of our great manufacturing country. But not so soon will be forgotten the refinement of mind, the ardour in scientific pursuits, the community of sentiments, and the warmth of friendship, which long cheered those scenes with their sunshine, and seem still to visit them with a distant gleam.

The passing of the Act of Parliament which ensured to Mr. Watt and his assignees the exclusive right to "make, use, "exercise, and vend" the steam-engines of his invention, now enabled him to arrange finally with Mr. Boulton the system on which their partnership and proposed manufacture of engines should be conducted. Of the great difficulties that still remained to be overcome in the further prosecution of their undertaking, we may form some faint estimate from the remarkable fact, that "at the period of the construction "of the first steam-engine upon the new principles at Soho, "the intelligent and judicious Smeaton, who had been invited "to satisfy himself of the superior performance of the engine "by his own experiments upon it, and had been convinced of "its great superiority over Newcomen's, doubted the practicability of getting the different parts executed with the requisite precision; and augured, from the extreme difficulty of

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* 'Account of the Life and Writings of Thomas Day, Esq.' (by Mr. Keir), p. 93. 1791.

" attaining this desideratum, that this powerful machine, in " its improved form, would never be generally introduced. " Such," adds the relator of this curious anecdote, the late Mr. Boulton,* " was at that period the low state of the me- " chanic arts, as fully to justify his opinion; but a school of " workmen, in every relevant branch, was speedily and suc- " cessfully instituted, and the forms and construction of the " machine were perfected with a skill and accuracy till then " unknown in the execution of large machinery."

The general curiosity that had begun to be excited throughout England as to the nature and comparative utility of the new engines, gave promise of at least a fair remuneration, if they could be successfully manufactured. So far back as 1771, Dr. Small had written to Mr. Watt,—" At present I am " to tell you something of consequence, about which it will " be proper to speak with Dr. Roebuck, to whom I offer my " best respects. A friend of Boulton and me in Cornwall " sent us word four days ago that four or five copper-mines " are just going to be abandoned, because of the high price of " coals, and begs me to apply to them instantly. The York " Building Company delay rebuilding their engine, with great " inconvenience to themselves, waiting for yours. Yesterday " application was made to me, by a mining company in Der- " byshire, to know when you are to be in England about fire- " engines; because they must quit their mine if you cannot " relieve them." And, in April 1775, " There are several " engines," says Mr. Boulton, " now wanted in Cornwall; " some of the proprietors of mines are impatient to know the " event of our Bill and the terms we will propose. I have " ventured to say to Mr. Glover, (who was requested to wait " upon us on that subject), that we will undertake and contract " to make an engine or engines capable of doing any quantity " of work that shall be requested and described, for as little " money as common engines will cost that are capable of " doing as much work; and we will guarantee them to do " that work with half the expense of fuel that common ones

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* Speech at the Public Meeting in Freemasons' Hall, in 1824.

"will require, provided we are allowed a sum that shall be "equal to its further savings over and above the said half." In August or September 1775, "Wilkinson hath been here, "and says that all his neighbours are impatient to see the "event of his engine. Some, he says, have suspended their "new erections until his is finished; and all of them, he "is sure, will have their engines altered, which he says "will be a better trade than new erections, and that work "alone will be sufficient for our lives." In March 1776, "I rejoice at the well-doing of Willey engine," (that which had been made for Mr. Wilkinson), "as I now hope and "flatter myself that we are at the eve of a fortune. I wish "to see you at Soho as soon as possible; there are many "things want you, and I find myself exceedingly hurried. "People are daily coming to see the engines. Cornwall "begins to inquire how we go on. I will reserve particulars "until I see you." And, later in the same year, "I have an "application for an engine from a distiller at Bristol, to raise "15,000 ale gallons per hour 60 feet high; I have another "for a coal mine in Wales, another for a Mr. Langdale, of "Holborn, a distiller, and another for Mr. Liptrap, at Mile End, "a distiller." "If we had a hundred wheels ready made, "and a hundred small engines like Bow engine, and twenty "large ones executed, we could readily dispose of them." "We have a positive order for an engine for Ting-Tang mine, "and from what I heard this day from Mr. Glover, we may "soon expect other orders from Cornwall. Our plot begins "to thicken apace, and if Mr. Wilkinson don't bustle a little "as well as ourselves, we shall not gather our harvest before "sunset. * * I perceive we shall be hard pushed in "engine work, but I have no fears of being distanced, when "once the exact course or best track is determined upon."

Yet, even then, the expectations of both the partners were very far indeed from being exorbitant, as to the profits to be derived from the important branch of manufacture on which they were preparing to enter. "It may be difficult," writes Mr. Boulton to Mr. Watt, in July 1776,—more than a year after the Act of Parliament had been obtained,—"to say

"what is the value of your property in partnership with me.
"However, I will give it a name, and I do say that I would
"willingly give you two, or perhaps three thousand pounds
"for the assignment of your third part of the Act of Parliament.
But I should be sorry to make you so bad a bargain,
"or to make any bargain at all that tended to deprive me of
"your friendship, acquaintance, and assistance, hoping that
"we shall harmoniously live to wear out the twenty-five
"years, which I had rather do than gain a Nabob's fortune
"by being the sole proprietor.

"I would without hesitation have sent you the assignment
"and the article of partnership, had it been in my power;
"but Mr. Dadley, the lawyer, is suddenly called to London,
"and it cannot be had before his return; but if you want to
"show it to any of your friends, you may give them a copy
"of the following heads, which I have extracted from our
"mutual missives, and are to the best of my knowledge all
"that our articles contain:—

"1st. You have assigned to me two-thirds of the Act of
"Parliament, on the following conditions:

"2nd. I to pay all expenses of making all the experiments,
and of obtaining the Act of Parliament, and all
"other expenses relative to the engine which were incurred
"before June, 1775; and I am also to bear all the expenses
"of future experiments, and all such money is to be sunk by
"me, and not to bear any interest, nor be carried to my
"account with you; but the experimental machines are to
"be my property, as they are purchased at my expense.

"3rd. I am to advance all the stock necessary for carrying
"on the engine trade, for which I am to receive lawful
"interest.

"4th. The profits arising from the trade, after paying or
"deducting interest, (as in 3rd,) workmen's wages, and all
"debts owing by our engine trade, to be divided into three
"parts; you are to take one-third, and I to take two-thirds.

"5th. You are to make drawings, surveys, and give directions;
the engine company to pay travelling expenses when
"upon business.

"6th. I am to take care that the books are kept accu-"rately, and that they are balanced once a year; and I am "also to assist in managing workmen, making bargains, or "doing whatever we may jointly think is for the interest of "the trade.

"7th. A book to be kept wherein are to be entered such "transactions as are worthy of record, and, when signed by "us both, to have the same force as our articles of partner-"ship.

"8th. Neither of us to alienate our shares without the "consent of the other; and if either of us should die, or be "incapacitated from acting for ourselves, the other is to be "sole manager, without control of heirs, executors, or assigns; "but the books are to be subject to their inspection, and the "acting partner to be allowed a reasonable commission for "his extra trouble.

"9th. The contract to continue in force for twenty-five "years from the 1st of June, 1775.

"10th. Our heirs, executors, &c., are bound to observe the "contract.

"11th. In case we both die, our heirs, &c., to succeed "upon the same plan.

"This is the essence of all that is contained in our articles "of partnership; but, being fearful of losing the post, I have "written in a great hurry, and have but ill expressed myself. "I wish I had more time to tell you all the circumstances "that have occurred in the engine trade, but that shall "be the subject of my next. All is well, and you'll be "quite charmed at the simplicity and quietness of Soho "engine."

This letter of Mr. Boulton was written on an interesting occasion, to serve as some guide to his partner in estimating the probable amount of his means, with a view to the preparation of a settlement on his second marriage. For it had now become evident, that, for the benefit of all parties, and to ensure the success of the new manufacture, it would be necessary for Mr. Watt to live in the immediate neighbourhood of Soho; he thus permanently abandoning his Scottish domicile, and migrating to England *animo remanendi*. Before doing so, however, having found that the burden of domestic affairs and the care of his children interfered seriously with his other pursuits, which had now become vitally important, he, after having remained for some years a widower, married a second time. The lady of his choice on this occasion was Anne, one of the daughters of Mr. Macgregor, a substantial citizen of Glasgow, who, under the instructions of his son-in-law, was the first to practise in this country the useful improvement of employing chlorine in bleaching, which Berthollet, its celebrated inventor, communicated to Mr. Watt. She was the mother of Gregory Watt, as well as of a daughter, both of whom she had the misfortune to lose by their premature death; and she died in 1832, in advanced old age, after witnessing the ripeness of the fame of her husband, of whom, M. Arago has justly said, “her various talent, soundness of judgment, and strength of mind, rendered her a worthy companion.”

Yet possibly, in the long forty-three years of his second wedlock, amid all the prosperity and fame by which they were marked, there may have been moments when his heart throbbed at the retrospect of an earlier time; and of an union, in days that were no more, with one whose loving hopes had sustained him in sorrow, without being permitted to taste of his joy; who had beheld his success and renown only by anticipation, and yet with all the firm faith of undoubting affection; and who had been summoned from his side just as he was about to emerge from the comparative obscurity in which he had long so wearily pined.

> “Tears, idle tears,—I know not what they mean,—
> “Tears from the depth of some divine despair
> “Rise in the heart, and gather to the eyes,
> “In looking on the happy autumn-fields,
> “And thinking of the days that are no more.”[*]

And, although we dare not, of course, assert that the sentiment which it expresses was ever familiar to the mind of tt, there also rises, unbidden, to our memory, one of the *ains* which Beranger has so musically sung :—

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[*] Tennyson, ‘The Princess.’

> " Mais elle avait, pour me charmer,
> " Ma jeunesse que je regrette :—
> " Ah, que ne puis-je vous aimer,
> " Comme autrefois j'aimai Rosette ! "
>
> " But she had one charm above thee,
> " In my youth which I regret :—
> " Why, alas ! can I not love thee
> " As of old I lov'd Rosette ! "

CHAPTER XVIII.

OFFER OF EMPLOYMENT IN RUSSIA — PROGRESS AT SOHO — [illegible] [illegible] [illegible] [illegible] — [illegible] AND [illegible] — M. DE PRONY — [illegible] [illegible] — [illegible] DUTIES OF THE NEW STEAM-ENGINE — PATENT OF [illegible] FOR COPYING-MACHINE — MACHINE FOR DRYING LINEN [illegible] [illegible] — PATENT OF [illegible] — "SUN AND PLANET WHEELS" — PATENT OF [illegible] — EXPANSIVE PRINCIPLE — DOUBLE-ACTING ENGINE — [illegible] [illegible] [illegible] [illegible].

At this critical turning-point of his life, Mr. Watt had rather a narrow escape from expatriation, and this country from losing all the benefit of his unrivalled career of invention. In 1773 he had received an invitation from his friend Robison to come to Russia, "where he had recommended him to fill "some station." But in the spring of 1775 an offer was made to him of employment in Russia, under the Imperial Government, which, at a somewhat earlier period, might probably have met with his thankful acceptance; for the salary promised was 1000*l.* per annum, and the duties required would have suited well his own inclinations and acquirements. The offer of the appointment in question, however, seems to have been ensured by, if it did not originate in, Mr. Boulton "having sounded his praises at the Ambassador's;" and he naturally preferred continuing, with him, those endeavours for a parliamentary prolongation of his first patent, on which their future association was to depend. "Your going to "Russia," says Mr. Boulton, "staggers me. The precariousness of your health, the dangers of so long a journey or "voyage, and my own deprivation of consolation, render me "a little uncomfortable; but I wish to assist and advise you "for the best, without regard to self;" and again, "I shall "rejoice at every good that befalls you; yet, nevertheless, I "find I love myself so well that I should be sorry to have "you go to Russia, and I begin to repent sounding your "trumpet at the Ambassador's." "Lord, how frightened I "was," writes the genial and hearty Darwin, "when I heard "a Russian bear* had laid hold of you with his great paw, "and was dragging you to Russia! Pray don't go if you "can help it. Russia is like the den of Cacus: you see the "footsteps of many beasts going thither, but of few returning. "I hope your fire-engines will keep you here."

The case also of a Captain Perry, (who, after having been engaged by Peter the Great as an engineer, and having served for many years in that country, had been obliged to take refuge in the house of the British Ambassador, and to return to England without receiving his pay), as well as representations of other similar instances, alarmed him for the consequences which might possibly again attend such despotic predilections; and recommended to his mind the less dazzling, but more secure destiny, of "a crust of bread and liberty." The Imperial family of Russia were then much interested in the various manufactures carried on at Soho, and greatly admired their products. In February 1776 the Empress stayed for some time at Mr. Boulton's house; "and a charming "woman she is," writes her hospitable entertainer.

It is rather a singular circumstance, that when, in 1816, his Imperial Highness the Grand Duke Nicholas of Russia, (the late Czar), applied at the Soho works for permission to view their interior, his application, although supported by a letter from Lord Sidmouth, was rejected. The objection felt, however, was not by any means to the potentate himself or his immediate friends, but to certain persons who followed in his suite, and whom there were good reasons for not initiating into the various processes of the manufacture.

Mr. Watt's labours at Soho soon began to manifest the great advantages which that establishment afforded in respect of materials, workmanship, and business connections. Fortunately, the completion of the reciprocating or condensing engine was not made to wait for that of the more troublesome and uncertain wheel-engine; but was at once proceeded with, under "the master's eye" and care. A cast-iron cylinder, over 18 inches in diameter, an inch thick, and weighing half a ton, but which seemed "tolerably true," "not perfect, but "without any very gross error," was procured from Mr. Wilkinson, and the piston, to diminish friction and the consequent wear of metal, girt with a brass hoop two inches broad: and although when first tried, "the engine goes marvellously bad; "it made eight strokes per minute; but, upon Joseph's "endeavouring to mend it, it stood still;" and that, too, though the piston was helped with all the appliances of "hat," papier maché, grease, black-lead powder, a bottle of oil "to drain through the hat and lubricate the sides," and an iron weight above all to prevent the piston leaving the papier behind in its stroke,—yet, after some imperfections of the valves were remedied, "the engine makes 500 strokes "with about two cwt. of coals;" and, in another month or two, with better condensation, it "makes 2000 strokes with one "cwt. of coals;" no bad work for such a machine, as yet but in its childhood. "The copper bottom for Bloomfield engine "is come," at the same time writes Mr. Boulton, "and Mr. "Hurst promises to forward the others directly. The new "forging-shop looks very formidable; the roof is nearly put "on, and the hearths are both built. The two small 7-inch "pumps for our own condenser are this day arrived; but we "can't bore them until we have got a block cast for fixing "the boring-knives in, which I shall hasten." And, within six months, there comes this order:—"Pray tell Mr. Wilkinson to "get a dozen of cylinders cast and bored, from 12 to 50 inches "diameter, and as many condensers of suitable sizes; the "latter must be sent here, as we will keep them ready fitted "up, and then an engine can be turned out of hand in two "or three weeks. I have fixed my mind upon making from "twelve to fifteen reciprocating, and fifty rotative engines "per annum."

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* "Which made old Ben and surly Dennis swear,
"No Lord's anointed, but a Russian bear!"
Pope's Imit. of Hor., B. ii. Ep. i., l. 388.

The new engines beginning now to be disseminated over many parts of England, and giving entire satisfaction to all who availed themselves of the invention, began to attract notice on the other side of the Channel. Within a couple of years after the passing of the Act of Parliament of 1775, negotiations were set on foot by MM. Perrier for using Mr. Watt's steam-engines to supply Paris with water; and, in 1778, the King of France, by a decree, granted to Messrs. Boulton and Watt an exclusive privilege to make and sell their engines in that country. This decree, according to the French patent law at that time, could not have the force of a patent till an engine had actually been subjected to the judgment of certain Commissioners appointed by the decree, and had been reported by them to be superior to the common engines. The trial engine, it was agreed, should be erected at the colliery of a M. Jary, near Nantes in Brittany; M. Jary, who was a very ingenious man, himself undertaking nearly the whole care of the erection.

"The sum of intelligence concerning Perrier," writes Mr. Boulton, "is, that, through interest, he has obtained the "King's *arrêt* empowering him to raise water from the Seine "to supply Paris, and erecting a company, copy of which I "shall send you; that W. Wilkinson went over to solicit "order for the pipes, &c.; that Perrier, when he went to "Broseley, was resolved to have common engines; that afterwards he was convinced that ours were much superior, and "then wanted Wilkinson to make them for him, as he did not "see the use of applying to us, [he] being out of our jurisdiction; that W. represented that he would be liable to prosecution, and that he was bound by honour and interest not "to do it but through us; that W. thought, as being out of "our jurisdiction, we should serve Perrier upon moderate "terms, should take out our premium in *actions*, which would "be saleable as bearing 6 per cent. interest; that W., if employed for pipes, &c., takes 100 shares at 50*l.* each.

"I answered, that Perrier had not behaved to us with prudent openness or consideration, and had attempted bribing "people to betray us at London; that we had friends in "France of interest, who had long ago assured us of the protection of the Crown, and that the State would see the "propriety of having us to erect our own machines; and that "if they did not, we would not serve Perrier so cheap a "they did; that some of our principal secrets were still "our own breasts; that it was more our interest to w "at home, without France was secured to us;" &c. ' "Perrier is a smith to trade, and reckoned a man of in "nuity; but his scheme is undigested, and he is igno "even of the proper method of conducting the water. ' "Lieutenant of Police is the ultimate judge of dispute "Perrier's scheme. Rather than fail, suppose we we "erect one or two engines for Perrier upon easy terms "vided he and his interest concurred in securing our pro "in France."

Early in 1779, Perrier visited Soho, "bargained o "moderate terms" for engines, and drawings for on sent to Jary by Mr. Watt, to be executed, it would in France. Finding, in May 1780, that the MM. Perri to erect three fire-engines, "whereof one according "plan, and the two others with 'changements qu'il av "'giné,' if we mean to keep this our kingdom of Fr "proper subjection," wrote Mr. Watt, "it will be ne "that one of ourselves go over there soon."

How far MM. Perrier showed off to advantage the of English design and French construction, appears f report of M. De Luc, "who was present at Paris when "called the Royal Academy to view the engine set ou "lo! it went *two* long strokes per minute; which he "owing to the want of the steam-case, which in haste "omitted. This being afterwards added, the engine wr "the rate of four strokes per minute, and he (De Lu "saw it go any faster."* This was rather a contras rate at which the Soho engines moved in their own and perhaps M. Perrier prevailed on the two other "variations which he had imagined," to mind their with more alacrity. But when Mr. Watt and Mr. visited Paris,† "We have also vindicated," writes Mr

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* Mr. Watt to Mr. Boulton, 29 October, 1782.

† To Dr. Roebuck, 3 February, 1787.

"the honour we were robbed of by M. Perrier's assuming the "merit of my invention; he said our coming was *un coup de* "*soufflet diabolique pour lui.* He has succeeded, however, in "having erected a most magnificent and commodious manu-"factory for steam-engines, where he executes all the parts "most exceedingly well. He is a man of abilities, and would "be very estimable if he were a little more just, (or more "honest)." And, in 1790, he again writes,* "I have a letter "from Mr. Levêque of July 4th. He has seen Perrier's "engine, which he does not like; says Mr. De Betancourt "instructed him how to make double engines, and has sent a "model of them to Spain, as he does of everything he sees; "and has written a memoir upon the effects of steam, which "will be published in Prony's 'Hydraulogie.' We must be "more and more careful in respect to foreigners." M. De Prony, (who usually spells the name of Watt either *Wats* or *Wast*), has an article in his 'Nouvelle Architecture Hydrau-'lique' (No. 1345, tome i., published in 1790),—"Comment "M. le Chevalier De Betancourt *a deviné le principe* d'une "machine à feu postérieurement construite par MM. *Wats* et "*Bolton*:"—on perusing which, it turns out that the engine alluded to was the double-engine; that the method M. De Betancourt took to "divine the principle," was to visit and inspect the engine itself at work at Soho; to observe the piston impelled both upwards and downwards by an equal force of steam; and then, having made a model, to get MM. Perrier to make an engine on the same construction as that which he had thus visited, inspected, and observed at work. A truly original, and doubtless an accurate, method, "*deviner* "*le principe.*"

M. De Prony's book is curious under another point of view. It contains a table of its own errata, in which there are enumerated no fewer than two hundred and seventy-eight; consisting of four great classes, viz., errata of the text, errata of the notes, errata of the tables, and errata of the "éclaircisse-"ments." But in all that catalogue, such errors as Wats and Wast for Watt, and Darmouth for Dartmouth, Durha for Durham, &c., &c., are not noticed, and pass "pour absolument rien." Therefore, to what the grand total of errata in the whole work might amount, we cannot even guess; and if to such as we have named were to be added the errata of the corrections of the errata,—(or errata *squared*),—and errata raised, as it were, to the third, or some even higher power, probably the work of Prony, like the machine of Marly as described by Belidor, might be found to be without a rival "dans ce monde."

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* To Mr. Boulton, 23 July, 1790.

But it is satisfactory to be able to add, that, on a personal acquaintance with M. De Prony, Mr. Watt found that he was a very estimable man; and that in any mistakes he had made as to the steam-engine, he had proceeded on erroneous information, and was anxious to correct them. "I acquit "him," writes Mr. W., in 1808, "of all blame or envious "intention; he was merely the chronicler of what was related "to him; and with such relators as Perrier and Betancourt "at his ear, what better could be expected? He knew nothing "of me or my works but what they pleased to relate. He is "himself a most ingenious, modest, and candid man, and "regrets much his having published what he has done; and "he offered to insert in his next publication whatever I "pleased to communicate on the subject."* In 1816 Mr. W. signed M. De Prony's certificate for the Royal Society; and, in returning it to Mr. Rennie, observed that he was glad to have had an opportunity of giving this testimony of his esteem for him.†

For many years after 1775, Mr. Watt resided chiefly in Birmingham, to be near the great manufacturing establishment to which his attention was now energetically devoted; but he was sometimes compelled to be absent, for long periods, in the mining districts of Cornwall,—a poor exchange, in his opinion, for the intellectual pleasures and hospitable sociality of the neighbourhood of Soho. His employments, during those intervals of forced absence, were, to a great extent, neither easy nor agreeable. He had, in the first place, to push his great invention into notice and use; in doing which, he had to contend not only with such obstacles as nature presented, in the dark abysses of desperately flooded mines, but also with the deeply-rooted prejudices of a rude and obstinate class of men, generally as incredulous of the powers of the new machine, as they were ignorant of the causes of the imperfections of the old ones. How little, too, the real merits of machinery were appreciated by those among whom he had to labour, appears from an amusing description he has given* of one of the first engines which he erected in Cornwall. "At present," he says, "the velocity, violence, "magnitude, and horrible noise of the engine give universal "satisfaction to all beholders, believers or not. I have once "or twice trimmed the engine to end its stroke gently, and "make less noise; but Mr. —— cannot sleep unless it seem "quite furious, so I have left it to the engine-man. And, by "the bye, the noise serves to convey great ideas of the power "to the ignorant, who seem to be no more taken with modest "merit in an engine than in a man." Naturally disinclined to solicitation, and averse to the coarse tumult of commercial business when conducted with inferior and illiberal minds, he was expected to obtain orders and extend connections; as well as to take charge, (as he did with much greater readiness), of the erection of the new engines, and of making experiments on all sorts of old ones. In public discussions at the meetings of mining adventurers, his arguments, founded on reason and science, too often met with jarring opposition,—sometimes even with ignorant contempt;—in private he had "constant bad headaches," and his "usual tendency towards "desponding views." As business increased, so did his troubles: "excessive difficulty in finding intelligent managing "clerks;"—"continual anxiety," (and frequent failure), "to "get the various parts of the metal-work executed exactly "according to his own drawings," which, it is needless to say, were made with laborious accuracy and clearness; so that, “ almost distracted with multiplicity of orders,” he sometimes fancied, he said, that he “ must be cut in pieces, and a portion “ sent to every tribe in Israel!” Then, as soon as the real value of the new engines began to be at all understood,—as soon as that water which was reckoned the “ heaviest” in the whole county, and which the sapient among the miners had, in the profundity of their wisdom, declared would never be “ forked,” not only was “ forked,” but showed, by the manner in which that process was accomplished, that the new engine “ might fork anything,”—to all his previous labours was added that hateful one of having to observe and restrain the piracies which forthwith began to be practised, secretly at first, but soon with greater frequency and daring.

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* Mr. Watt to Mr. James Watt, jun., 10th November, 1808.

† To Mr. Rennie, 5th December, 1816.

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* In a letter to Mr. Boulton from Truro, without date.

The bare and miserable aspect of the country in which his head-quarters were at such times most commonly fixed, increased the gloom of the months he was compelled to spend there. Cornish mines are far from resembling the fabled scenery of the golden age; and the following description of one, though drawn with a lively pencil, and inserted in a work of fiction, is, we believe, true to Nature:—“ It was an “ ugly, uninviting place to look at, with but few visible signs “ of wealth. The earth, which had been burrowed out by “ those human rabbits in their search after tin, lay around in “ huge ungainly heaps; the overground buildings of the “ establishments consisted of a few ill-arranged sheds, already “ apparently in a state of decadence; dirt and slush, and “ pools of water confined by muddy dams, abounded on every “ side; muddy men, with muddy carts and muddy horses, “ slowly crawled hither and thither, apparently with no object, “ and evidently indifferent as to whom they might overset in “ their course. The inferior men seemed to show no respect “ to those above them, and the superiors to exercise no “ authority over those below them. There was a sullen “ equality among them all. On the ground around was no “ vegetation; nothing green met the eye; some few stunted “ bushes appeared here and there, nearly smothered by “ heaped-up mud, but they had about them none of the "attractiveness of foliage. The whole scene, though consisting of earth alone, was unearthly; and looked as though "the devil had walked over the place with hot hoofs, and "then raked it with a huge rake."* The "dismal weather "did not tend to raise his spirits;" those wilds, he says, might be defined "a tract of hills without dales," where the roads went "straight up the hills without flinching," and where,—(the force of savage misery could no further go!)— "*the enginemen actually eat the grease for the engine!*" Some of his letters indeed remind one, although, of course, in all the sobriety of engineering prose, of the strains in which Ovid bewailed his exile to the remote and savage Pontus;— "peace of mind, and delivery from Cornwall, is my prayer," was his desponding message to Soho in 1782. But, as the Muse did not cease, amid the horrors of barbarian skies, to cheer with her smiles the lonely hours of the expatriated Roman poet, so the spirit of Invention did not forsake her favourite son in his Cornish solitude; and even his '*Tristia*' give token of her inspiration.

The copper companies becoming bankrupt, or, at least, insolvent, in rapid succession, and many of the mines being already unworkable from the increase of water, while the low price of copper would not admit of the removal of that obstacle by the old and expensive means, were all circumstances which, however unpropitious at first sight, really proved advantageous to the cause of the new steam-engine, by compelling the adoption of every principle by which economy of fuel and labour could be attained.

Nevertheless, the result to Boulton and Watt in the way of emolument was for several years questionable enough; for in 1780, "it appears," says Mr. Watt,† "by our books, "that Cornwall has hitherto eat up all the profits we have "drawn from it, and all we have got by other places, and a "good sum of our own money to the bargain." Even in 1783 he writes,—"we have altered all the engines in Cornwall but "one, and many in other parts of England; but do not acquire

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* 'The Three Clerks,' vol. i., p. 199.

† To Mr. Boulton, 31 October, 1780.

" riches so fast as might be imagined; the expenses of carryi
" on our business are necessarily very great, and have hithert
" consumed almost all our profits; but we hope to do bett
" by continuing our attention and exertions, and by mult
" plying the number of our works."* Yet the state of ma
ters from which the new steam-engine redeemed the fai
mines, is thus, at the same period, described by him:
" Chacewater Company sunk 50,000*l.* and upwards in setti
" that mine to work; and whether they have recovered it
" yet seems uncertain, although the mine has been tolera
" prosperous. Wheal Virgin and Co. lost 28,000*l.* in
" months' unprosperous working. Poldice has sunk a
" great sum, and is not now gaining nor saving. It has
" 35,000*l.* to fit up and drain Wheal Virgin in this wor
" and it costs above 10,000*l.* a-year to draw the water,
" all that can be done for them. Pool adventurers have
" near 14,000*l.*, and have no great prospect of reco
" any part of it. Roskeere has been long languishin
" does not now pay costs. At Dolcoath Mine it is sai
" use 500*l.* of timber per month, and a new kibble
" above a ton weight is worn out in a fortnight. I
" fully 15 minutes to draw a kibble of ore there, which
" only about 3 cwt. On the average, above ⅔ of t
" drawn is barren stones. It cost three years' work
" believe, as many thousand pounds, to sink a new
" that mine:—every fathom of an engine-shaft that
" under the engine costs from 50*l.* to 100*l.* Unite
" have been at death's door, and are still in a totteri
" Wheal Union adventurers, after working near thre
" were glad to sit down with a loss of 7000*l.* or 8000*l*
" had not furnished them with more effectual means
" ing the water, I believe almost all the deep mines l
" abandoned before now."

With Mr. Watt, the whole of the period of whic
now speaking, whether passed by him at Birming
Cornwall, or elsewhere, was one of the most continu

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* Mr. Watt to Mr. Macdowal, 3 January, 1783.

satile and active exertion, and the most profusely fertile in mechanical invention, of the whole of his life. This may be said to have been the case more especially as regards the first ten years of the time in question, viz. from 1775 to 1785, during which he secured, by five several patents, the invention of the machine for copying letters and drawings, together with those almost innumerable improvements on the steam-engine, of infinite ingenuity and value, which he had made subsequent to that of the separate condenser; besides originating other contrivances, which, although not included by him in patents, might have made both the fortune and the reputation of many a minor adventurer in that line.

Taking his patents in their chronological order, the first, (subsequent to that of 1769), is that "For a new method of "copying letters and other writings expeditiously,"—which passed the Great Seal on the 14th of February, 1780, the specification being enrolled on the 31st of May following. The first idea of this invention is believed to have originated in Mr. Watt's mind from his perception of the advantages of a scheme proposed by Dr. Darwin, of a sort of duplex pen which he called a bigrapher, but which we are not aware that there is any great reason for supposing to have been very successfully employed in practice. His bigrapher perhaps resembled that notable "instrument for writing many copies "of the same thing at once," contrived and patented by Sir William Petty in 1648, which "when it came to be tried "was found to take considerably more than twice the time to "produce its two copies that the common pen took to produce one." *

To Dr. Darwin accordingly was sent one of the early intimations of the completion of the modern copying-machine:—"I have fallen on a way of copying writing chemically, "which beats your bigrapher hollow. I can copy a whole-sheet letter in five minutes. I send a copy of the other "page enclosed for your conviction, and I tell you further "that I can do still better than that copy." † To Mr. Boul-

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* Romance of the Peerage, vol. iv. p. 258-9.

† The letter is without further date than Birmingham, 1779.

ton,* "I send you enclosed some of Mr. Nobody's draugh " with authentic copies of them. * * The copy will contin " to grow blacker as other writing does, and I fancy you w " find the originals rather blacker than they were bef " copying, and, as far as I can judge, not in the least defac And in December 1779, he writes to Dr. Black, "In rela " to the copying scheme, the state of it at present i " follows:—I have given in a petition for a patent, and " now in train; but as my occupations and health c " permit me to follow that business myself, I have tak " two partners—Mr. Boulton, who is to be at the expe " the patent, and Mr. Keir, who is to manage the busin

" In brief, the first idea was the forcing the ink t " thin paper, so as to appear on the other side; the " the improving the colour by wetting the paper " astringent; the third, the depriving astringents " colour, without depriving them of their effects as astr " fourthly, managing the operation so as to prev " original being defaced, or forced through to the ot " but the greatest part resides in the mechanical m " All this to yourself *only* at present."

Specimens of the result of the process its invento himself by supplying to others of his correspondent ing been mysteriously done, like the magical typo Fust, " *Non Atramento aut Plumali Cannâ, sed Art* " *Novâ.*"

The difficulty of finding materials suitable in al to the new process, led him to make a great numbe riments, especially in regard to the ink which was fit used in order to insure clearness and durability in t without injury to the original; and, finding that the sumed by that long series of trials interfered incon with his other not less urgent occupations, he as partners in the copying-press business, as mention both Mr. Boulton, (who was at the expense of the pat their mutual friend Mr. Keir, who was possessed of and well-informed mind, and whom his own inclinations had led to the study of chemistry and the application of it to the arts. That the manufacture of the copying-presses prospered under their joint management, is attested by the number of public, mercantile, and other offices, as well as of private individuals, that were supplied with those useful implements; which have, indeed, been ever since considered in this country as indispensable to the rapid, easy, and safe transaction of business in every extensive concern.

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* 28 June, 1779.

To the inventor this ingenious contrivance brought its own reward:—for he says in writing to one of his correspondents, (to Mr. H. B. Way, 27th March, 1809),—" It is gratifying that " you find the copying-machine useful to you. It has been so " much so to me, for the last twenty-six years, that it has been " worth all the trouble I had with it, had it been attended " with no other profit." Early in 1781, his friend Dr. Patrick Wilson wrote to him on this subject, giving a very useful hint, which was carried out in practice by the contrivance of *damping-boxes* made of wood, lined with tin-foil or sheet-lead, with a lid fitting close to the interior of the sides, so as to admit of either a small or a large quantity of copying-paper being damped at one time:—" I have never met with any" thing in the way of improvement which has given me more " pleasure than your copying-machine; and I have become " your debtor for one furnished me by Mr. G. Hamilton, now " in use, and which I have strongly recommended to others.

" The interest I take in everything relating to you, as one " of our oldest friends, induces me on the present occasion to " communicate some things which I flatter myself may not " be unworthy of your attention, in the way of obviating some " objections against the use of the machine. What I have " chiefly in view relates to the preparing and moistening the " paper. Many have said that a work of this nature is " foreign to the train of things in a counting-house; and " when set about in hurried seasons and in candle-light, " would necessarily prove highly inconvenient. These kinds " of surmises, which I had frequently met with in conversa" tion before getting my machine, led me to think of a

" remedy which I have now tried, and found to answer
" and which has since reconciled many here very compl
" to your whole scheme.

" My method is to prepare in daylight, and whe
" leisure, by the wetting book, as much paper as will
" for a month, which I preserve in that state of moistur
" keeping the leaves betwixt boards of wainscot with
" FOIL next the paper. I have three sets of these board
" the half-folio, quarto, and next size of paper; but the
" foil is an inch beyond the leaves all round, so as to
" down; the more effectually to prevent the moisture
" escaping. The uppermost board is loaded with sheet
" and the undermost has a handle, to draw them mor
" veniently from the under shelf of the copying-table,
" they always lie when not in use. Yesterday I tried
" sheets preserved moist in this way for 23 days, and th
" was extremely distinct and equal, owing to the m
" being more uniformly diffused than in the comm
" * * But there may be still more commodious wa
" of applying this principle in practice.

" It will be of importance also to the success of y
" that the rollers do not split in the keeping.*
" showed symptoms of this kind after the first three
" my room, upon which I immediately anointed the e
" with soft pomatum, which stopped the progress of the

It is hardly necessary that we should here desc
simple process, so well understood at the present da
posing the letter to be copied, interleaved with damp
copying-paper and oiled paper, or pasteboard, to pre
a few seconds between the rollers of a rolling-pres
fact, to any adequate and equable pressure, not too p
so that the ink may be duly impressed on the copy
being also forced through the letter-paper so as to in
appearance of the letter. The machines manufact
this purpose by James Watt and Co. (under which f

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[*] This refers to some of the first rollers, which were made of lignum-vitæ; but on the drawing attached to the specification they had been described as being "wood
" talline;" and in practice,
cast-iron, or, in some cases,
were preferred and generall

Soho copying business was conducted), were, with hardly an exception, made with rollers; at first of lignum-vitæ, but afterwards of iron; the wood having been found, from the alternations of damp and dryness, to have a tendency to crack or split. By other manufacturers in later times, a screw or lever press has been frequently substituted for rollers, as occupying less room; and this circumstance has sometimes led to comparisons being instituted between what has been called Mr. Watt's copying-press on the one hand, and what has been called the modern one on the other, not always to the advantage of the former, on account of its greater bulk and weight.

It was, however, also proposed by Mr. Watt in his specification, to use, instead of a rolling-press, *a screw-press*, " or " any other pressure sufficient " for the purpose; and in the screw-press delineated in the drawing which accompanied it,* will at once be recognised what, under a variety of forms and unimportant modifications, is in fact the common modern copying-press. But it will still, we think, be found, that the rollers, when properly managed, do their work more effectually than the screw; and that Mr. Watt's preference of them in his own practice was therefore not unfounded.

On the immense utility of the contrivance, it is quite unnecessary to enlarge; but we may observe that for copying drawings,—a purpose for which, though expressly specified, it has, we believe, been in general but seldom used,—its merits are quite as great as for that to which it is more commonly applied. The drawing being made, as writings ought to be, with ink sufficiently mucilaginous for the purpose, the copy can be taken either on the common transparent copying-paper, or on unsized drawing-paper;—in the latter case, the copy being reversed as the impression of an engraved plate, care must be taken that any letters of reference, or descriptive titles, are not added to either the original or the copy until after the latter has been thrown off. For this purpose, pressure between rollers is decidedly preferable to that obtained by the screw. In the establishment at Soho, it has been the practice, by the aid of this excellent invention of its great founder, to retain copies of the drawings of all the engines sent out from that manufactory.

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* 'Mechanical Inventions of James Watt,' vol. iii. plate II. fig. 3.

To this short notice of the copying-machine we have only to add, that the late Mr. James Watt, jun., having, in the course of his extensive business correspondence and frequent absence from home, felt the inconvenience of separation from so useful an assistant in the labours of the bureau as the machine thus invented by his father, contrived an extremely useful portable form of it. In this, small brass rollers are used instead of the larger and more ponderous iron ones; and the whole apparatus, with a full supply of stationery, &c., is commodiously arranged in a travelling desk of mahogany, little more than a foot square, and not above six inches high. The exact dimensions of one now before us are 13½ × 11½ inches; height 5 inches.

Of the same date as the copying-machine was Mr. Watt's invention of a machine for drying linen and muslin by steam; a drawing of which, with explanations, he sent to Mr. Macgregor, his father-in-law, on the 4th of February, 1781. "It "consists," he then wrote, "of three cylinders of copper "which the cloth must turn over and under while they are "filled with steam. I have also added to it a drawing of the "method by which the water condensed may be returned to "the boiler. The joinings of the parts may be made good "with soft solder. * * I presume you understand the "cloth is to be alternately wound off and on the two wooden "rollers, by which means it will pass over the three cylinders "in succession." Mr. Macgregor had it executed, under the superintendence of Dr. Irvine and Mr. Gilbert Hamilton, by John Gardiner, an ingenious artisan whom Mr. Watt had often employed as one of his journeymen, in earlier years, when resident in Glasgow. "This," he wrote in 1814 to Sir David Brewster, "I apprehend to be the original from which such "machines were made, and which, I believe, is claimed by "somebody else. If you think it worth publication, I shall "cause a copy [to be made] and send it you—it possesses

" some merit." The machine is described in Brewster's Edinburgh Encyclopædia, vol. xviii. p. 384*, and the drawing of it is engraved on plate DXI. of that work, figs. 7, 8, 9, and 10.

On the 25th of October, 1781, Mr. Watt took out his third patent, (the second of the steam-engine series,) of which the specification was enrolled on the 23rd of February, 1782, " for " certain new methods of applying the vibrating or recipro- " cating motion of steam or fire engines, to produce a con- " tinued rotative motion round an axis or centre, and thereby " to give motion to the wheels of mills or other machines." The application for this patent was rendered necessary by the difficulties that had been experienced in working the steam-wheels or rotatory engines, such as that described in the specification of 1769; and by Mr. Watt having been unfairly anticipated by Wasborough, &c., in the application of the crank. " I know the contrivance," he writes to Mr. Boulton in April, 1781, " is my own, and has been stolen from me by " the most infamous means, and, to add to the provocation, a " patent surreptitiously obtained for it. * * I know from " experiment that the other contrivance which you saw me " try, performs at least as well, and has, in fact, many advan- " tages over the crank." And again, in the same month, " If " the King should think Matt. Wasborough a better engineer " than me, I should scorn to undeceive him; I should leave " that to Matthew. The conviction would be the stronger, " as the evidence would be undeniable!"

In the Specification, no fewer than five different methods are enumerated, by any one of which the proposed end might be attained without the intervention of a crank; all of them admitting, as therein mentioned, of many varieties. The fifth is that commonly known as the " Sun and Planet " wheels."

To all of the five methods which it describes, where heavy wheels or swift motions are not otherwise necessary for the uses to which the methods are to be applied, the specification recommends that a fly-wheel should be applied to equalise the motion. But, as Mr. Watt has observed, his application of the double engine, (described in the specification of 1782,) to those rotative machines, rendered unnecessary the counter-weight, and produced a more regular motion; "so that," he says, "in most of our great manufactories these engines now "supply the place of water, wind, and horse mills; and, "instead of carrying the work to the power, the prime agent "is placed wherever it is most convenient to the manufac-"turer."—(Notes to Robison, p. 135.)

"From the time of the first invention of the improved "engines," (Mr. Watt writes to his son, 10th November, 1808), "I was desirous of applying them to giving motion to "mills in some better way than by raising water to turn a "water-wheel. One method I described in the patent," (i.e. of 1769): "the reason why that method was not pursued, it "is now unnecessary to enter upon. Of another method I "made a model soon after, which still exists in an unfinished "state, and several more have since been devised by myself "and others. All these were self-acting rotative engines, not "derived from the rectilinear motion of a piston in a cylinder. "They have their respective merits; but instead of being "more simple in their construction, they are more complex "than those derived from reciprocating motions, and more "difficult in execution.

"The first I know of, of the latter kind, was one I saw at "Hartley Colliery about 1768, which consisted of a toothed "sector on the end of the working-beam, working into a "trundle, which, by means of two pinions with ratchet wheels, "produced a rotative motion in the same direction, by both "the ascending and descending stroke of the arch; and by "shifting the ratchets the motion would be reversed at plea-"sure, when one of the ratchets was arrived at the bottom. "It was employed to draw coals out of a pit, had no fly-"wheel, and went sluggishly and irregularly; the name of "the inventor I have long since forgotten. One Stewart had "a patent for an engine which produced a rotative motion, by "a chain going round a pulley and round two barrels fur-"nished with ratchet wheels, with a weight suspended to the "free end of the chain, which served to continue the motion during the return of the engine. I have never seen this, but believe there was no fly. Whether this was the same as Mr. Clarke's or not, I know not. The next I know of is Matthew Wasborough's, which was virtually the same as that I saw at Hartley, but Matthew *had added a fly-wheel*, which, as far as I know, was the first time that had been employed for that purpose. I at present recollect nothing of Fitzgerald's rotative engine, but think it was something of the ratchet kind.

“The true inventor of the crank rotative motion was the “ man, (who unfortunately has not been deified), that first “ contrived the common foot-lathe.” (In another letter to his son about the same date, Mr. Watt says, “The real “ inventor of the rotative motion was the man, be he Chinese, “ Indian, Arabian, Greek, or Goth, who first made a common “ foot-lathe. The applying it to the engine was merely “ taking a knife to cut cheese which had been made to cut “ bread.”) “My share in the application I remember perfectly to have been as follows:—One of Matthew Wasborough's rotative engines was erected at Birmingham, for a “ rolling-mill, and was much talked of. This set me again “ to think upon the subject, and brought to my remembrance “ my former meditations upon the crank, the date of which I “ cannot ascertain.” It appears to have been at all events prior to 1771, for early in that year Mr. Watt writes:—“I “ have at times had my thoughts a good deal upon the “ subject, but have not hit upon anything decisive: only in “ general it appears to me that a crank of a sufficient sweep “ will be by much the sweetest motion, and perhaps not the “ dearest, if its durability be considered.” “I was, however, “ desirous to render the motion continued and equable without “ a fly-wheel, the regulating power of which I did not then “ fully appreciate, nor the advantage to be derived to the “ engine from the crank causing the motion of the engine to “ be slow at the beginning and end of the stroke; which, “ however, a few experiments with other contrivances soon “ made me sensible of. I then resolved to adopt the crank; “ and, to equalise the power, I proposed to adoptt wo cylinders

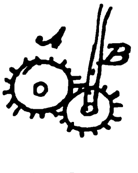
" acting upon two cranks fixed upon the same axis at an
" angle of 120 from each other, and to place a weight on the
" circumference of the fly-wheel at an angle of 120 from each
" of the cranks; which weight was to be so adjusted as to act
" when neither of the cranks could do so, and, consequently,
" to render the power in itself nearly equable. Or to place
" the two cranks at right angles to each other, and to load
" the outer end of the working-beams of the two cylinders
" with weights equal to half the power of the respective cylin-
" ders, which might act during the time of the ascents of the
" respective pistons.

"Of this I caused a model to be made, which performed
" to satisfaction. But, being then very much engaged with
" other business, I neglected to take a patent immediately,
" and, having employed a blackguard of the name of Cart-
" wright, (who was afterwards hanged), about this model, he,
" when in company with some of the same sort who worked
" at Wasborough's mill, and were complaining of its irregu-
" larities and frequent disasters, told them he could put them
" in a way to make a rotative motion which would not go
" out of order nor stun them with its noise, and accordingly
" explained to them what he had seen me do. Soon after
" which, John Steed, who was engineer at Wasborough's mill,
" took a patent for a rotative motion with a crank, and
" applied it to their engine. Suspicions arising of Cart-
" wright's treachery, he was strictly questioned, and confessed
" his part in the transaction when too late to be of service to
" us. I had afterwards a conversation with Steed upon the
" subject, who said that he had made the invention before he
" was informed of Cartwright's communication, and had taken
" his ideas from the common foot-lathe; and that Cartwright's
" information had no other effect than to accelerate his taking
" out the patent. How this was, I know not; it is certainly
" possible that Steed might have invented it; but what I have
" related is the fact as far as concerns my invention.

"Finding the door thus closed upon us, and circumstances
" making us unwilling to go to law with the patentees, which
" could only have had the effect of throwing the invention

" open to the public if we had succeeded, we judged it better " to let it remain with them,—who did not seem capable of " doing us much harm,—than to let it get into the hands of " men more ingenious, being sensible at the same time that " their rotative motion could not do much good, without it " were attached to our engines. We therefore thought it " better to take a patent for several contrivances on the same " principle, which the former patentees never thought proper " to call in question. The revolving wheels was the one which " we principally adopted; but the advantages of the crank in " point of simplicity have made it now to be generally used, " and the other to be laid aside, perhaps for ever."

With regard to the fifth method specified, that, namely, of the "sun and planet wheels," which perhaps was the most ingenious and elegant, as well as the most practically useful, of all the five, it is to be observed that, although its invention dated from an *earlier* period in Mr. Watt's life, it seems to have been revived in the interval between taking out the patent and giving in the specification. Living at that time in Cornwall, Mr. Watt went to Penryn on the 25th of July, 1781, and made the affidavit to accompany his petition for the patent; and on the 3rd of January, 1782, he writes to Mr. Boulton:—" I wrote to you on the 31st, since which I " have tried a model of one of my old plans of rotative " engines, revived and executed by Mr. M[urdock], and which " merits being included in the specification as a fifth method; " for which purpose I shall send a drawing and description " next post. It has the singular property of going twice " round for each stroke of the engine, and may be made to " go oftener round, if required, without additional machinery. " The wheel A is fixed at the end of an axis which carries a " fly; the wheel B is fixed fast to the con- " necting-rod from the working-beam, and " cannot turn on its axis, and is confined by " some means, so as always to keep in con- " tact with the wheel A; consequently by " the action of the engine it goes round it and " causes it to revolve on its axis; and if the wheels are



"equal in the number of their teeth, A will make "revolutions while B goes once round it." Two later,* "I send you the drawings of the 5th method, "thought to have sent you the description complete, but "late last night before I finished so far, and to-day "headache, therefore only send you a rough draft of "The drawing is made to ½-inch scale for 6-feet stroke "must be reduced to the ¼-inch. * * This 5th "makes an exceeding good motion, and may in many "be very useful, from its peculiar properties." And days later still,—"I wrote to you on Saturday, with dr "of the 5th method of rotatives, and enclosed I se "complete specification of that method."

The drawings for this specification were made, in du by Mr. Watt's own hand; one of them "on stamped "ment for want of plain," and the other, "in an "manner upon vellum, being the neatest drawing," "I ever made: and [I] have improved the constru "several of the machines, and represented their sta "several other parts necessary. The double-toothed [the sun and planet motion], "admit of several "applications, one of which admits the rotative whe "in the middle of an axis, and that was the origin He says in another letter, before the specification wa in, "I have thought on some other methods by wh "tive motions may be made, but they are inferior "specified, and I feared the specification would have "four yards long." †

While preparing the specification of the patent of 1 the five methods of producing a continuous rotative round an axis, from the vibrating or reciprocating m steam-engines, so as to give movement to mill-wo Watt was already arranging the contents of anothe of quite as great importance. The title of the new which passed the Great Seal on the 12th of March, 1782, was quite a general one; being "for certain new improvements "upon steam or fire-engines, for raising water, and other "mechanical purposes, and certain new pieces of mechanism "applicable to the same." But in the specification, which was enrolled on the 4th of July, 1782, are comprehended the following "new improvements:"—

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* To Mr. Boulton, 5 January, 1782.

† See the specification printed in vol. iii. of the 'Mechanical Inventions of James Watt,' 1854, pp. 36 to 54; and the relative dra graved on Plates III. I and VII. of the same volu

1. The use of steam on the expansive principle; together with various methods or contrivances, (six in number, some of them comprising various modifications), for equalising the expansive power.

2. The double-acting engine; in which steam is admitted to press the piston upwards as well as downwards; the piston being also aided in its ascent as well as in its descent by a vacuum produced by condensation on the other side.

3. The double-engine; consisting of two engines, primary and secondary, of which the steam-vessels and condensers communicate by pipes and valves, so that they can be worked either independently or in concert; and make their strokes either alternately or both together, as may be required.

4. The employment of a toothed rack and sector, instead of chains, for guiding the piston-rod.

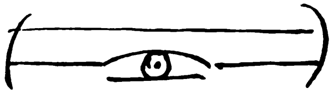
5. A rotative engine, or steam-wheel.

1. It appears from one of Mr. Watt's letters, (to Mr. Boulton, 19th November, 1781), that he had first thought of the expansive engine in 1767; and had also explained it to Mr. Smeaton, at Soho, some years previous to 1781. Its principle is a curious one, and appears at first paradoxical; for, in fact, by cutting off the supply of steam at a certain point before the steam-vessel or cylinder is full, the same effect is produced as if the steam-vessel had been entirely filled with steam: the expansion, or elastic force which the steam exerts, doing the same work that in the other case would have been done by a greater quantity of steam, and, therefore, a further expenditure of fuel. The proportion of steam specified by Mr. Watt as being most convenient for

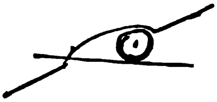
admission, in common use, was one-fourth of the contents of the steam-vessel; producing an effect equal to more than one-half the effect that would have been produced had steam been admitted to enter freely into the cylinder during the whole length of the stroke of the piston. But he adds that any other proportion would produce similar [proportional] effects, and that in practice he did vary the proportion accordingly.

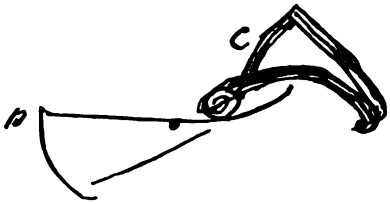
But the powers thus exerted by the steam being unequal at different periods of the stroke, while the resistance to be overcome, or work to be done, by the engine, was supposed to be equal throughout the whole length of each stroke, it was necessary to equalise the power of the engine; for doing which six different methods are specified. And, as of two of them, (viz. the first and third), there are two varieties, and of another, (viz. the fifth), there are four varieties, we have here no fewer than eleven varieties of such equalising machinery described, for particulars of all of which reference must be made to the specification, and relative plates.

To exhibit some of those "equalisers" in their embryo stage, we may give from Mr. Watt's correspondence the following extracts, written between the date of his making the affidavit to accompany the petition, and the enrolment of the specification. The extracts are all from letters written to Mr. Boulton, from Cosgarne, (in Cornwall), and are dated respectively the 9th, 11th, and 14th of February, 1782:—"I "have nothing new to advise you of, except a new method of "an equalising beam, by causing the gudgeon to change its "place, thus—

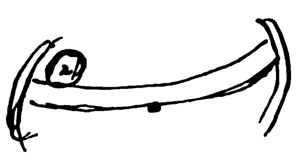


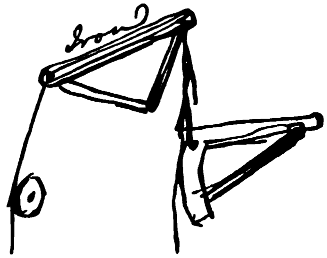
"The working-beam is made hollow on the under-side, and "rests upon a roller which has an axis through it, and this "axis has a wheel fixed upon each end of it, unconnected "with the roller, but connected together by means of the

" axis. At beginning of the stroke the roller and beam " stand thus—  ; but as the engine-end " descends, the curve forces the roller to travel towards the " pump-end, and *vice versâ.* N.B. The wheels, and not the " roller, rest upon the fulcrum or support. I have also made " sketches of some equalising beams, which perform by means " of a roller acting upon a curve in the nature of the working " gear; the engine pulls by the arch C, and the pump is hung " to the arch P; the roller travels about the length of the " stroke, and the curve permits a perfect equalisation;"—" I " have filled one whole sheet, royal, with equalisers, and shall " probably fill another before I am done;"—" I remark what " you said in your last about equalisers, and had thought of



" the same; below are two new ones. But the flyer is the " best of all, and will prove the true equaliser, and will have " much less friction than any other. It may, however, be " combined with some of the most simple ones; and the





" weight raised by the back-stroke may be placed so far " above the centre as in some measure to equalise itself."

2. The double-acting engine, as appears from the letter to Mr. Boulton already referred to, where Mr. Watt calls it the "double cylinder," was also imagined by him about 17[illegible]. A large drawing of it on parchment, now in our possession, made from a sketch by Mr. Watt, was laid before the Committee of the House of Commons when Mr. Watt was soliciting the Act of Parliament for the extension of the patent, in 1774–5. The reason of it not having been sooner secured by a patent, was the difficulty which its inventor "had "encountered in teaching others the construction and use of "the single engine, and in overcoming prejudices:"—and the patent of 1782 was, even then, taken out only in consequence of Mr. Watt "finding himself beset with an host of plagiaries "and pirates." In the same time, and with almost the same machinery, the engine on this new principle was enabled to do double the work of the single engine, independent of the additional saving resulting from the use of the expansive principles already explained, by which it could be used as a double-acting expansive engine; in which case the fourth, fifth, and sixth of the contrivances for equalising the powers of the steam are specified as being peculiarly applicable.

One of the earliest double-acting engines completed for sale was one of those for the Albion Mills, erected in 1786, at the south-east corner of Blackfriars Bridge. "The mention of "the Albion Mills," says Mr. Watt, "induces me to say a "few words respecting an establishment so unjustly calum"niated in its day, and the premature destruction of which, "by fire, in 1791, was, not improbably, imputed to design. "So far from being, as misrepresented, a monopoly injurious "to the public, it was the means of considerably reducing the "price of flour while it continued at work.

"It consisted of two engines, each of fifty horses' power, "and twenty pairs of millstones, of which twelve or more "pairs, with the requisite machinery for dressing the flour "and for other purposes, were generally kept at work. In "place of wooden wheels, always subject to frequent derange"ment, wheels of cast-iron, with the teeth truly formed and "finished, and properly proportioned to the work, were here

" employed; and other machinery, which used to be made of " wood, was made of cast-iron, in improved forms; and I " believe the work executed here may be said to [have] " form[ed] the commencement of that system of mill-work " which has proved so useful to this country. In the con- " struction of that mill-work and machinery, Boulton and " Watt derived most valuable assistance from that able " mechanician and engineer, Mr. John Rennie, then just " entering into business, who assisted in planning them, and " under whose direction they were executed. The engines " and mill-work were contained in a commodious and elegant " building, designed and executed under the direction of the " late Mr. Samuel Wyatt, architect." *

We may add, that Mr. Peter Ewart was then Rennie's apprentice, was sent for from Scotland expressly to assist in the erection of those mills, and was employed for four years upon them as a millwright; when his great mechanical talents and industry sufficiently recommended him to his future employers, patrons, and friends, Messrs. Boulton and Watt.†

We have here spoken of the "double-acting" engine, (a name sometimes applied to it on its first introduction), to distinguish it from the next of the new improvements included in the specification of 1782, viz.:—

3. The double, or *compound* engine; the nature and advantages of which are thus shortly described by Mr. Watt:—" A " new compound engine, or method of connecting together the " cylinders and condensers of two or more distinct engines, so " as to make the steam which has been employed to press on " the piston of the first, act expansively upon the piston of " the second, &c., and thus derive an additional power to " act either alternately or conjointly with that of the first " cylinder." ‡

4. Toothed rack and sector, instead of chains, for guiding the piston-rod. In consequence of Mr. Watt's beautiful inven-

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* Notes on Robison, p. 137.

† See the 'Address of the President,' James Walker, Esq., 'of the 'Institution of Civil Engineers, to the 'Annual General Meeting, January '17, 1843.'

‡ Notes on Robison, p. 150.

tion of the Parallel Motion, made at no distant date from that of this specification, the rack and sector may be looked on as having been only a temporary expedient to avoid the inconveniences which had been found to result from the old system of chains connecting the piston-rod with the beam.

5. Rotative engine, or steam-wheel. For the reason already mentioned when treating of the patent of 1781, viz. that "self-" acting rotative engines, not derived from the rectilinear " motion of a piston in a cylinder, instead of being more " simple in their construction, are more complex than those " derived from reciprocating motions, and more difficult in " execution," it seems unnecessary to enlarge on this article, which is fully described in the specification.*

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* See the specification of this third steam-engine patent, printed in vol. iii. of the 'Mechanical Inven' tions of James Watt,' 1854, pp. 55 to 87; and the relative drawings, engraved in the same volume, Plates VIII., IX., X., XI., XII., XIII., XIV., XV., XVI., XVII., XVIII., and XIX.

CHAPTER XIX.

STEAM TILT-HAMMER — PATENT OF 1784 — PARALLEL MOTION — LOCOMOTIVE STEAM-CARRIAGES — COUNTER — THROTTLE-VALVE — GOVERNOR — STEAM BAROMETER OR FLOAT — STEAM-GAUGE — INDICATOR — MOST INVENTIVE PERIOD OF MR. WATT'S LIFE — DEATH OF HIS FATHER — PATENT OF 1785 — CONSUMPTION OF SMOKE.

A FAVOURITE employment of Mr. Watt in the workshops at Soho in the latter months of 1783 and earlier ones of 1784, was to teach his steam-engine, now become nearly as docile as it was powerful, to work a tilt-hammer for forging iron and making steel. So far back as 3 May, 1777, he had informed Mr. Boulton that "[John] Wilkinson is going to work "in the forge way, and wants an engine to raise a stamp of "15 cwt. thirty or forty times in a minute. I have set Webb "to work to try it with the little engine and a stamp-hammer "of 60 lbs. weight. Many of these *battering rams* will be "wanted if they answer." During his long absence, and constant occupation in Cornwall, this labour seems to have been intermitted; and we do not find it resumed in earnest till November, 1782. Then "the rotative motion and mill "part answered to every expectation, but the hammer-frame "and anvil-block were not sufficiently secured, which, how"ever, I have given orders for doing. And as the engine has "a great overplus of power, I mean to increase the weight of "the hammer to about 1½ cwt., and to cause it to make 250 "or 300 strokes per minute, by diminishing the height it "rises to 9 or 10 inches. The present facts are, cylinder, 15 "inches diameter, and 4 feet stroke, 25 strokes per minute; "hammer makes 6 blows per stroke of the engine; fly under "5 cwt., and 7 feet diameter; hammer 120 lbs., and 18 inches "wide; it strikes a good blow, and forges iron very well. "The *camms* were wood, and were cut all to pieces by the "anvil-block sinking. I have ordered steel ones to be made, "which I expect will stand it."* On the 30th of November he says,—"I saw the tilt go admirably from 16 to 24 strokes "per minute, and it could have gone much faster, but our "men could not work the iron under it. Joseph said that "yesterday they made it go 28 strokes per minute, which is "much more than the engine should do by my calculation; "but in the midst of our glory, the hammer helve broke: it "appears to have been rotten. The steel *camms* answer very "well, and the whole will answer better when made to have "a less lift and more strokes, as it will then answer for a "common tilt for steel; at present the blow is so strong, that "we dare not attempt to *hack* a piece of iron under 1½ inch "square, otherwise it knocks it to pieces. By the help of "some more weight on the outer end of the beam, it goes so "regular that you cannot tell when the engine is going out "or when coming in." On the 12th of December,—"I went "out to Soho yesterday forenoon, hoping the engine would "be ready for trial, but it was not. In the evening they "wrought it 2 hours, 240 blows per minute, rise of hammer "8 inches." On the 13th,—"We have tried our little tilting-"forge hammer at Soho, with success. The following are "some of the particulars:—cylinder 15 inches diameter, 4 "feet stroke, strokes per minute 20. The hammer-head, "120 lbs. weight, rises 8 inches, strikes 240 blows per minute. "The machine goes quite regular, and can be managed as "easily as a water-mill. It requires a very small quantity "of steam, not above half the contents of the cylinder per "stroke. The power employed is not more than ¼ of what "would be required to raise the quantity of water which "would enable a water-wheel to work the same hammer with "the same velocity." Next month, they were "making an-"other to work a hammer of 700 lbs., which will soon be at "work." This was for Mr. John Wilkinson at Bradley, and, on the 27th of April, 1783, Mr. Watt writes, "We have had a "trial of our new forge-engine at Bradley; cylinder 42 inches "diameter, 6 feet stroke. Makes from 15 to 50 (even 60

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[*] To Mr. Boulton, 28 November, 1782.

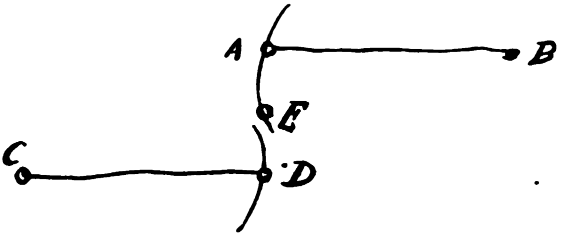
"strokes per minute) at pleasure, works a hammer of 7½ cwt. "raised 2 feet high, which makes 6 strokes per stroke of the "engine, and has struck 300 blows per minute; we are, how- "ever, going to make it strike only 4½ blows per stroke of "the engine, because we want the latter to go 20 strokes per "minute, and they want only 90 blows of the hammer in "that time; but will increase the weight of the hammer to "10 cwt. N.B. The engine is to work two hammers, but is "capable of working four hammers, of 7 cwt. each."

In a letter written on the previous day, he had said, with excusable pride, "I believe it is a thing never done before, "to make a hammer of that weight make 300 blows per "minute; and, in fact, it is more a matter to brag of than "for any other use, as the rate wanted is from 90 to 100 "blows, being as quick as the workmen can manage the iron "under it."

This most valuable application of steam-power was, accordingly, reserved for insertion in yet another patent, which Mr. Watt took out on the 28th of April, 1784. The relative specification, enrolled on the 25th of August in that year, may probably be viewed as second in importance to none of those prepared by Mr. Watt subsequent to that of the Separate Condenser in 1769; as, besides many improvements now of minor consequence, such as steam-wheels, balancing of pump-rods, communication of motion from the same engine to two separate primary axes, and apparatus for opening the regulating-valves with rapidity, it contains various methods of converting a circular or angular motion into a perpendicular or rectilineal motion,—one of those methods being the well-known and much-admired *Parallel Motion*;—a method of working a tilt-hammer for forging iron, making steel, &c., by steam;—and the application of the steam-engine to give motion to wheel carriages for carrying persons or goods.

Of the last-mentioned invention, and of its inventor's views of the subject of locomotion by steam, in general, we shall presently treat. Of the invention of the Parallel Motion,—a beautiful mechanical puzzle which different philosophers have attempted to explain in various ways, but which has uniformly commanded the admiration of all who either comprehend the principles on which it acts, or behold the smoothness, orderly power, and "sweet simplicity" of its movements, —we find the following account in a letter from Mr. Watt to his son, already cited; (Mr. Watt to Mr. James Watt, 10th November, 1808):—

"The idea originated in this manner. On finding double "chains, or racks and sectors, very inconvenient for commu- "nicating the motion of the piston-rod to the angular motion "of the working-beam, I set to work to try if I could not "contrive some means of performing the same from motions "turning upon centres, and after some time it occurred to "me that AB, CD, being two equal radii revolving on the "centres B and C, and connected together by a rod AD, in "moving through arches of certain lengths, the variations "from the straight line would be nearly equal and opposite, "and that the point E would describe a line nearly straight. "and that if for convenience the radius CD was only half of "AB, by moving the point E nearer to D, the same would "take place; and from this the construction, afterwards called "the parallel motion, was derived. * * Though I am not "over anxious after fame, yet I am more proud of the parallel "motion than of any other mechanical invention I have ever "made."



See also on this subject Mr. Watt's Appendix to 'Robison on 'Steam and Steam-engines,' pp. 152, 153 ;where he mentions that "the invention was made in the latter end of 1783."

The manner in which we find the contrivance of this admirable piece of mechanism first recorded in his corre- spondence, although six months later than the date thus assigned to it by Mr. Watt, is interesting:—"I have started "a new hare. I have got a glimpse of a method of causing "a piston-rod to move up and down perpendicularly, by only "fixing it to a piece of iron upon the beam, without chains, "or perpendicular guides, or untowardly frictions, arch-heads, "or other pieces of clumsiness; by which contrivance, if it "answers fully to expectation, about five feet in the height "of the [engine-] house may be saved in 8-feet strokes, which "I look upon as a capital saving; and it will answer for "double engines as well as for single ones. I have only tried "it in a slight model yet, so cannot build upon it, though I "think it a very probable thing to succeed, and one of the "most ingenious simple pieces of mechanism I have con-"trived, but I beg nothing may be said on it till I specify."* And again, on the 11th of July:—"I have made a very large "model of the new substitute for racks and sectors, which "seems to bid fair to answer. The rod goes up and down, "quite in a perpendicular line, without racks, chains, or "guides. It is a perpendicular motion derived from a com-"bination of motions about centres, very simple, has very "little friction, has nothing standing higher than the back "of the beam, and requires the centre of the beam to be "only half the stroke of the engine higher than the top of "the piston-rod when at lowest, and has no inclination to pull "the piston-rod either one way or another except straight up "and down. It has rather more power at beginning and end "of the stroke than in the middle,—I think about one-sixth; "which I believe will do no hurt in rotative motions, and "little in any case. Beams mounted in this way need no "arches; and the whole iron-work will not, I think, be more "than chains, martingales, and their appendages, if quite so "much. However, don't pride yourself on it; it is not fairly "tried yet, and may have unknown faults. Where it is "used, the beams will be best above the centre of motion, "which will answer double engines very well, and may in "most cases be dispensed with in the others." On the 21st of October, 1784, he writes:—"The new central perpen-"dicular motion answers beyond expectation, and does not "make the shadow of a noise."*

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* To Mr. Boulton, 30 June, 1784.

The manufacturing profits which Boulton and Watt stipulated to receive from the Cornish miners who used their engines, were at first one-third of the savings of fuel made by each engine, when compared with a common one burning the same kind of coal, to be paid annually or half-yearly, with an option of redemption at ten years' purchase. In point of fact, they did not receive nearly that proportion; but still, such was the agreement made, and such, had it been honestly adhered to on the side of the miners, would have been the amount paid. It therefore became essential to ascertain the exact number of strokes made by each engine during any given time, and that in a way that should be independent of all possibility of deception or interference by those employed about the engine. This object was fully attained by Mr. Watt's invention of his "Counter;" a neat piece of clockwork containing a pendulum, a train of wheels with an escapement, and several dials like those of watches graduated with numbers, and each with its index: the first index marking, on its own dial, tens; the next, hundreds; the next, thousands; and so on in the same ratio up to any required amount. Eight dials, with their respective indices, were found sufficient to count the strokes of an engine going constantly, day and night, for a year. The pendulum was fixed horizontally and transversely across the width of the beam, with the axes of the wheels vertical, while the beam was horizontal, and the piston at the middle of a stroke: thus at every inclination of the beam either downwards or upwards, the pendulum moved across the width of the box, and, by the vibratory movement of the pendulum and pallets, the escapement wheel was turned one tooth for each complete stroke of the piston. And the whole work of the counter being enclosed in a box which was fastened by screws from within on the great beam of the engine and then locked, was inaccessible except to those in possession of the key.

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* The specification of the patent of April 28th, 1784, is printed in the 'Mechanical Inventions of James 'Watt,' 1854, vol. iii., pp. 88 to 114; and the relative drawings are engraved on Plates XX., XXI., XXII., XXIII., XXIV., XXV., XXVI., XXVII., and XXVIII.

Some other equally ingenious inventions, introduced by Mr. Watt at various periods, very greatly increased the utility of the engine; and although it would be vain here to attempt to give anything like a complete enumeration of his almost endless contrivances connected with the details of the different parts, yet we may mention especially, as among the leading improvements, the Throttle-Valve, the application of the Governor, the Barometer or Float, the Steam-Gauge, and the Indicator.

The great use of the Throttle-Valve was to regulate the speed of the rotative engines for mill-work,.a matter essential to their application to cotton-spinning and many other like purposes; it is described by Mr. Watt as " a circular plate of " metal, having a spindle fixed across its diameter, the plate " being accurately fitted to an aperture in a metal ring of " some thickness, through the edgeway of which the spindle " is fitted steam-tight, and the ring fixed between the two " flanches of the joint of the steam-pipe which is next to the " cylinder. One end of the spindle, which has a square upon " it, comes through the ring, and has a spanner fixed upon it, " by which it can be turned in either direction. When the " valve is parallel to the outsides of the ring, it shuts the " opening nearly perfectly; but when its plane lies at an " angle to the ring, it admits more or less steam according to " the degree it has opened; consequently the piston is acted " upon with more or less force. For many purposes engines " are thus regulated by hand at the pleasure of the attendant; " but where a regular velocity is required, other means must " be applied to open and shut it, without any attention on " the part of those who have the care of it.

" For this purpose Mr. Watt had various methods, but at " last fixed upon what he calls the Governor, consisting of a " perpendicular axis, turned by the engine: to a joint near the " top of this axis are suspended two iron rods carrying heavy " balls of metal at their lower ends, in the nature of pendu- " lums. When this axis is put in motion by the engine, the

" balls recede from the perpendicular by the centrifugal
" and, by means of a combination of levers fixed to th
" upper end, raise the end of a lever which acts upon
" spanner of the throttle-valve, and shuts it more or
" according to the speed of the engine, so that as the vel
" augments, the valve is shut, until the speed of the
" and the opening of the valve come to a maximum,
" balance each other. The application of the centri
" *principle* was not a new invention, but had been appli
" others to the regulation of water and wind mills,' and
" things; but Mr. Watt improved the mechanism by
" acted upon the machines, and adapted it to his engi

" Such," says M. Arago,—in describing Mr. Watt's
tion to the steam-engine of the "*governor*," or "regu
" centrifugal force,"—" was its efficacy, that there
" seen at Manchester a few years ago, in the cotto
" Mr. Lee, a man of great mechanical talents, a clo
" was set in motion by the steam-engine used in t
" and which marked time very well, even beside a
" pendulum clock." *

" From the beginning, Mr. Watt applied a gauge
" the height of the water in his little boiler, which
" of a glass tube communicating at the lower end
" water in the boiler, and at the upper end with
" contained in it. This gauge was of great use in h
" ments, but in practice other methods are adopted.
" always used a barometer to indicate the degree o
" tion in his engines. Sometimes that instrume
" usual, a glass tube 33 or 34 inches long, imm
" bottom in a cistern of mercury, and at top comm
" by means of a small pipe and cock with the conden
" oscillations are in a great degree prevented by
" the passage for the steam by means of the cock.

" But, as glass tubes were liable to be broken by t
" men, barometers were made of iron tubes, in the

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* Translation of the 'Eloge of 'Watt,' p. 87, ed. 1839.—Mr. Lee was a brother of Sophia and Harriet Lee, the well-known authoress 'Canterbury Tales,' (1797 of several other works.

" inverted syphons, one leg about half the length of the " other; to the upper end of the long leg a pipe and cock " were joined, which communicated with the condenser; a " proper quantity of mercury was poured into the short leg " of the syphon, and naturally stood level in the two legs: a " light Float with a slender stem was placed in the short leg, " and a scale, divided into half-inches, applied to it, which " (as by the exhaustion the mercury rose as much in the long " leg as it fell in the short one), represented inches on the " common barometer.

" The Steam-Gauge is a short glass tube with its lower end " immersed in a cistern of mercury, which is placed within " an iron box screwed to the boiler steam-pipe, or to some " other part communicating freely with the steam, which, " pressing on the surface of the mercury in the cistern, raises " the mercury in the tube, (which is open to the air at the " upper end), and its altitude serves to show the elastic power " of the steam over that of the atmosphere.

" These instruments are of great use when they are kept " in order, in showing the superintendent the state of the " engine; but slovenly engine-tenders are but too apt to put " them out of order, or to suffer them to be so. It is the " interest, however, of every owner of an engine to see that " they, as well as all other parts of the engine, are kept in " order.

" The barometer being adapted only to ascertain the degree of exhaustion in the condenser where its variations " were small, the vibrations of the mercury rendered it very " difficult, if not impracticable, to ascertain the state of the " exhaustion of the cylinder at the different periods of the " stroke of the engine; it became therefore necessary to contrive an instrument for that purpose that should be less " subject to vibration, and should show nearly the degree of " exhaustion in the cylinder at all periods. The following " instrument, called the Indicator, is found to answer the end " sufficiently. A cylinder about an inch diameter, and six " inches long, exceedingly truly bored, has a solid piston accurately fitted to it, so as to slide easy by the help of some

" oil; the stem of the piston is guided in the direction of the " axis of the cylinder, so that it may not be subject to jam, " or cause friction in any part of its motion. The bottom of " this cylinder has a cock and small pipe joined to it, which, " having a conical end, may be inserted in a hole drilled in " the cylinder of the engine near one of the ends, so that, by " opening the small cock, a communication may be effected " between the inside of the cylinder and the indicator.

" The cylinder of the indicator is fastened upon a wooden or " metal frame, more than twice its own length; one end of a " spiral steel spring, like that of a spring steel-yard, is attached " to the upper part of the frame, and the other end of the " spring is attached to the upper end of the piston-rod of the " indicator. The spring is made of such a strength, that " when the cylinder of the indicator is perfectly exhausted, " the pressure of the atmosphere may force its piston down " within an inch of its bottom. An index being fixed to the " top of its piston-rod, the point where it stands, when quite " exhausted, is marked from an observation of a barometer " communicating with the same exhausted vessel, and the " scale divided accordingly."

" The joints of the cylinder, and other parts of Newcomen's " engines, were generally made tight by being screwed together upon rings of lead covered with glazier's putty, " which method was sufficient, as the entry of small quantities of air did not materially affect the working of those " engines where only a very imperfect exhaustion was required. But the contrary being the case in the improved " engines, this method would not answer Mr. Watt's purpose. " He at first made his joints very true, and screwed them " together upon pasteboard, softened by soaking in water, " which answered tolerably well for a time, but was not sufficiently durable. He therefore endeavoured to find out " some more lasting substance; and, observing that at the " iron foundries they filled up flaws by iron borings or filings " moistened by an ammoniacal liquor, which in time became " hard, he improved upon this by mixing the iron borings or " filings with a small quantity of sulphur and a little sal-

" ammoniac, to which he afterwards added some fine sand " from the grindstone-troughs. This mixture being moistened " with water and spread upon the joint, heats soon after it is " screwed together, becomes hard, and remains good and " tight for years; which has contributed in no small degree " to the perfection of the engines. Mr. Murdock, much about " the same time, without communication with Mr. Watt, " made a cement of iron borings and sal-ammoniac, without " the sulphur. But the latter gives the valuable property of " making the cement set immediately."

To those who study the physiological development of the mind, every fact in the history of an intellect such as that of Mr. Watt, is of peculiar interest. For of all the mental powers, the faculty of mechanical inventiveness is perhaps the most rare; and Mr. Watt has long been, by the consent of the greatest men of science in the world, placed " at the " head of all inventors in all ages and nations."* It thus becomes worth remarking, that the ten years subsequent to 1775, during which he took out his five last patents, and made those other improvements on the steam-engine of which we have now given some account, were the period during which he seems to have combined the greatest maturity with the greatest activity of intellect; and that the time of his life which they comprehended, was from his fortieth to his fiftieth year. The labour involved in devising and adapting to practice his new inventions, and in preparing the drawings and descriptions of them required for the specifications of his patents, was, indeed, only a small part of that which he then underwent; for he was, for a great portion of the time, as we have already mentioned, daily occupied in superintending the erection of new engines or the alteration of old ones,—in watching and defeating the continual attempts made to pirate his inventions and rob his partner and himself of their moderate gains,— in "giving," as his son has said, " the constant " attention necessary to the concerns of a nascent manu-

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* Sir James Mackintosh, Speech at the Meeting at Freemasons' Hall, 1824.

“ factory, and himself writing volumes of other lett
“ business, which alone would have furnished full e
“ ment even to an industrious intellect.” “His mind
continues the same excellent authority, “ had been
“ affected by his unavoidable absence from the de
“ of his aged father;* and during the greater par
“ time, I well remember seeing him suffer under m
“ sick headaches, sitting by the fireside for hours
“ with his head leaning on his elbow, and scarcel
“ give utterance to his thoughts. It was unquestic
“ busiest as well as the most anxious period of hi
“ fraught with the most important results.”

Often, in the course of the period of which we
speaking, especially towards its close, we find hi
complaints of his bad health, of what he call
“ stupidity,” and “ want of the inventive faculty;”
which, had they issued from less sincere lips, r
been almost deemed ironical, but were with him,
thing else that he uttered, the honest expression
feelings of his mind. Towards the close of 17
“ my own health is so bad that I do not think I c
“ much longer, at least as a man of business.”
“ help being dispirited, because I find my head fail
“ business an excessive burden to me, and little
“ any speedy release from it. Were we both
“ healthy, I see no reason to despair, but very m

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* Mr. Watt, senr., died at Greenock in August, 1782. On the 1st of September his son writes, on receiving the intelligence of that event, to Mr. Cochrane:—“ Yesterday brought me your letter of the 23rd, containing the afflicting news of the death of my worthy and kind father. When we consider his death as a removal from a state of pain and disease to a state where we must hope that he will meet the reward of a well-spent and laborious life, we cannot with reason bewail his loss; yet there is something so afflicting in the thought of the final, solemn de-
“ parture of a belov
“ revered parent, that
“ been, by his long i
“ clining state, prepare
“ the account of it
“ much pain. * *
“ It behoves me no
“ lay aside unavailing
“ thank God that he
“ preserved me from
“ tunes.
“ My wife and f
“ well, and my child
“ mising, which circum
“ great reason to be gr
“ ever I may be other

" trary; however, we must do the best we can, and hope for " quiet in Heaven, when our weary bones are laid to rest:"— " on the whole, I find it now full time to cease attempting to " invent new things, or to attempt anything which is attended " with any risk of not succeeding, or of creating trouble " in the execution. Let us go on executing the things " we understand, and leave the rest to younger men, who " have neither money nor character to lose." Early in 1786, also, he writes:—" in the anguish of my mind amid the vexations occasioned by new and unsuccessful schemes, like " Lovelace, I ' curse my inventions,' and almost wish, if we " could gather our money together, that somebody else should " succeed in getting our trade from us." And, in June of the same year, " I should have written to you long ago, but have " really been in a worse situation in some respects this spring " than I have ever been in my life. The illness I was " seized with in London in the spring greatly weakened me " both in body and mind; and, I believe, was brought on by " over-exertions, endeavouring to get home as soon as possible. The bodily disease has in great measure subsided; " but an unusual quantity of business, which by Mr. Boulton's " frequent and long absences has fallen wholly on me, and " several vexations, with the consequent anxious thoughts, " have hitherto prevented my mind from recovering its " energy. I have been quite effete and listless, neither " daring to face business, nor capable of it; my head and " memory failing me much; my stable of hobby-horses " pulled down, and the horses given to the dogs for carrion. " In such a situation it requires something very pressing, or " very animating, to make one put pen to paper. I have " had serious thoughts of throwing down the burthen I find " myself unable to carry, and perhaps, if other sentiments " had not been stronger, should have thought of throwing off " the mortal coil; but, if matters do not grow worse, I may " perhaps stagger on. Solomon said that in the increase of " knowledge there is increase of sorrow: if he had substituted " *business* for knowledge, it would have been perfectly true."

The history of one other patent will exhaust the series of those taken out by Mr. Watt. On the 25th of March, 1785, he wrote to Mr. Boulton, "I think we are in the way of "getting quit of smoke in the engines;" and on the 10th of September in the same year, to Mr. De Luc, "I have some "hopes of being able to get quit of the abominable smoke "which attends fire-engines. Some experiments which I "have made promise success. It is not on Mr. Argand's "principle, but on an old one of my own, which is exceed"ingly different." On the 9th of October, "We had a fair "trial yesterday of a large furnace to burn without smoke "under the big boiler, at Soho, that used to poison Mr. B.'s "garden so much, and it answered very well, as far as we "could judge from a wet furnace, and without the engine "being at work."

Of the date of this invention being devised or completed by Mr. Watt, we have no more exact information; but in September of the same year in which he obtained his patent for it, he mentioned that the principle on which it proceeded was "an old one of his own." Until that time, he does not appear ever to have tried it on a large scale; but, both then and since, it has, we believe, been always found to answer well in practice. "It is astonishing," writes his son Mr. James Watt to him from Manchester in 1790, "what an "impression the smoke-consuming power of the engine has "made upon the minds of everybody hereabouts; nobody "would believe it until the engine was set a-going, and even "then they scarcely trusted to the evidence of their senses. "You would be diverted to hear the strange hypotheses "which have been started to account for it. However, it has "answered one extremely good end,—it has made your engines general topics of conversation, and consequently universally known; which they were by no means before in "this country." And on the 14th of June, 1785, he took out a patent "for certain newly improved methods of constructing furnaces or fire-places for heating, boiling, or evaporating of water and other liquids which are applicable to "steam-engines and other purposes, and also for heating, "melting, and smelting of metals and their ores, whereby

" greater effects are produced from the fuel, and the smoke is " in a great measure prevented or consumed," which newly improved methods he describes to consist "in causing the smoke " or flame of the fresh fuel, in its way to the flues or chimney, " to pass together with a current of fresh air through, over, " or among fuel which has already ceased to smoke, or which " is converted into coke, charcoal, or cinders, and which is " intensely hot, by which means the smoke and grosser parts " of the flame, by coming into close contact with, or by " being brought near unto the said intensely hot fuel, and " by being mixed with the current of fresh or unburnt air, " are consumed or converted into heat, or into pure flame " free from smoke."

" I put this in practice," he continues,—" First, by stopping up every avenue or passage to the chimney or flues, " except such as are left in the interstices of the fuel, by " placing the fresh fuel above, or nearer to the external air, " than that which is already converted into coke or charcoal; " and by constructing the fire-places in such manner that the " flame, and the air which animates the fire, must pass downwards, or laterally or horizontally, through the burning " fuel, and pass from the lower part, or internal end or side " of the fire-place, to the flues or chimney. In some cases, " after the flame has passed through the burning fuel, I " cause it to pass through a very hot tunnel, flue, or oven, " before it comes to the bottom of the boiler, or to the " part of the furnace where it is proposed to melt metal, or " perform other office, by which means the smoke is still " more effectually consumed. In other cases I cause the " flame to pass immediately from the fire-place into the space " under a boiler, or into the bed of a melting or other " furnace." He varied the figure or form and proportions of the fire-places, &c., but in all cases the principle was the same; the fresh or raw fuel being placed next to the external air, and so that the smoke or flame passed over or through the coked or charred part of the fuel.

" Secondly," he goes on, " in some cases I place the fresh " fuel on a grate as usual, and beyond that grate, at or near

" the place where the flame passes into the flues or chimneys, " I place another small grate, on which I maintain a fire of " charcoal, coke, or coals which have been previously burnt " until they have ceased to smoke; which, by giving intense " heat and admitting some fresh air, consumes the smoke of " the first fire.

" Lastly, be it remembered," he concludes, " that my said " new invention consists only in the method of consuming the " smoke and increasing the heat, by causing the smoke and " flame of the fresh fuel to pass through very hot tunnels or " pipes, or among, through, or near fuel which is intensely " hot, and which has ceased to smoke, and by mixing it with " fresh air when in these circumstances; and in the form and " nature of the fire-places herein mentioned, described, and " delineated: the boilers and other parts of the furnaces " being such as are in common use. And be it also remembered, that these new invented fire-places are applicable to " furnaces for almost every use or purpose." *

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* The Specification, which was enrolled on the 9th of July, 1785, is printed in the 'Mechanical Inventions of James Watt,' 1854, vol. iii. pp. 115 to 121; and the relative drawings are engraved on Plates XXX., XXXI., XXXII., and XXXIII. of the same work.

CHAPTER XX.

HISTORY OF THE DISCOVERY OF THE COMPOSITION OF WATER — MR. WATT'S STUDY OF CHEMISTRY — STATE OF THAT SCIENCE PREVIOUS TO 1783 — BLACK AND PRIESTLEY — MACQUER — VOLTA — WARLTIRE — CAVENDISH — DREW NO CONCLUSION FROM HIS EXPERIMENTS — LAVOISIER — HIS KNOWLEDGE OF THE EXPERIMENTS OF CAVENDISH, AND OF THE CONCLUSIONS OF WATT.

IN 1783,—one of the busiest of those ten years of his life which may thus be said to have teemed with experiments and inventions,—Mr. Watt had the further honourable distinction of making and publishing his famous discovery of the Composition of Water. It must be added, though we do so with regret, that, as in his greatest mechanical inventions, so in this matter also, he experienced the unpleasant necessity of vindicating his own just claims from the unexpected, and, as we believe, most men will be of opinion, the unjustifiable, interference of others. It was an occasion, however, on which the firmness, moderation, and true greatness of his mind were signally manifested; and the circumstances of which, as displayed in his Correspondence on the subject, have contributed in every way to increase his good name.

His principal inventions connected with the steam-engine, with all their prodigious results, were founded, as we have seen, on the attentive observation of great philosophical truths; and the economy of fuel, increase of productive power, and saving of animal labour, which gradually ensued, all originated in the sagacious and careful thought with which he investigated the nature and properties of heat. The department of physical science with which, next to mechanics, he may be said to have been at one time most familiar, and which long continued in some measure to occupy his leisure hours, was Chemistry. With what success he studied it, we know from the testimony of the most eminent among his contemporaries who directed their attention espe-cially to that subject, and many of whom were his frequent correspondents. "He was equally distinguished," said the late illustrious President of the Royal Society, Sir Humphry Davy, "as a natural philosopher and a chemist, and his "inventions demonstrate his *profound knowledge* of those sci-"ences."* The numerous experiments which he made with a view to the attainment of the great principles of which he was in search, are further commended by the same accom-plished and able judge, as difficult, delicate, and refined.

It is stated in the Memoirs of his friend and neighbour, t celebrated botanist Dr. Withering, that "in his estimati "Mr. Watt's abilities and acquirements placed him next "not superior, to Newton;"† a judgment dictated, no dou by the kind partiality of a friend, but showing the estima in which Mr. Watt's talents were held by an able and cerning man of science. How intently he watched the p nomena, how deeply he penetrated into the causes of chem action, might be conceived from his friend Robison's des tion of him as "a philosopher in the most exalted sens "the word, who never could be satisfied with a conject "knowledge of any subject, and who grudged no labou "study to acquire certainty in his researches."‡ The hig merit certainly attaches to his chemical discoveries, and interest must be felt by all who attend to the history of origin and progress, from the fact that he was in this, i almost every other part of learning, self-taught. He has self, on one of the very few occasions on which he ever m public any of his writings through the medium of the p (almost all the others being only communications to the R Society, which were ordered to be printed,) taken pain correct the statements of Professor Robison on this p That gentleman, in dedicating to him his edition of Black's Lectures, called him Dr. Black's pupil, declared he had attended two courses of his lectures, and even all

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[*] Speech in 1824.—Translation of Arago's 'Eloge,' p. 191.

[†] Tracts and Memoir of Dr. Withering, by his Son, 1822. p. 46.

[‡] Preface to Black's Lecture

to his professing to owe his improvements on the steam-engine to the instructions he had received from that eminent teacher. This, however, is altogether erroneous; and Mr. Watt has lamented* that the necessary avocations of his business at that time prevented his attending either Dr. Black's or any other lectures. But he repeatedly acknowledged the information and pleasure he derived from the conversation of that enlightened philosopher, as well as from the friendship of such men as Robert Simson and Dr. Dick, both distinguished cultivators of kindred branches of natural knowledge.

In establishing himself at Soho, he retained his habits of intimate correspondence with Dr. Black, who had then, for more than twenty years, made known his discovery of carbonic acid gas, and for at least sixteen had annually explained his theory of latent heat in his lectures, in which, also, for the first time, he developed the doctrine of the capacities of bodies for heat, (or that of specific heat); and who, after spending ten years of academical labour in the University of Glasgow, had, in 1766, accepted that professorial chair in Edinburgh, which for thirty years longer he continued to render famous.†

We have much pleasure in being able, on indisputable authority, to attribute the public announcement of Dr. Black's theory of latent heat to a period considerably earlier than had formerly been named, even by Dr. Black's zealous admirer and pupil, Lord Brougham. His Lordship says that Dr. Black meditated on that theory, investigated it by experiment, and taught it in his lectures, at least as early as 1763. But the following extract from his letter to Mr. Watt, of 15th

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* See his Preface to his edition of Dr. Robison's Articles, 'Steam' and 'Steam-Engine.'

† Dr. Ferguson, as quoted by Robison in his Preface to the Lectures, and repeated, among many others, by Lord Brougham, says that Dr. Black died on the 26th November, 1799. But Dr. Black's last letter to Mr. Watt, which is indorsed by Mr. Watt, "*his last letter*," and in which he mentions that he had been slightly unwell, but was then better, was written on the 2nd December of that year. In fact, on the 11th December, Professor Robison wrote to Mr. Watt, that his much respected friend had died on the Friday preceding, viz. the 6th December. Ferguson also says, that he died in the seventy-first year of his age; but he really died in his seventy-second year, for in a letter to Mr. Watt of 8th April, 1798, he writes "I have now finished "my seventieth year."

March, 1780, furnishes information more precise, and assigns with certainty a much earlier date to so admirable a discovery. "I began," says the Doctor, "to give the doctrine "of latent heat in my lectures at Glasgow, in the winter "1757-58, which I believe was the first winter of my lecturing "there, or, if I did not give it that winter, I certainly gave "it in the 1758-59, and I have delivered it every year "since that time in my winter lectures, which I continued to "give at Glasgow until winter 1766-67, when I began to lecture in Edinburgh."

In the same letter he mentions by name many distinguished foreigners, as well as natives of this country, who had attended some of the earliest courses of his lectures, and had then heard his explanations of that remarkable theory; adding, that about 1760-61, or soon after, he read a paper on the subject, in the Philosophical or University Club at Glasgow, and thus concluding:—"I could bring a multitude of "other evidences to prove the early date of my doctrines on "this subject." We need hardly observe, that none who are duly aware of the modesty and carelessness of fame, the scrupulous veracity, and exact observation of facts, which distinguished that truly learned and excellent person, can imagine any other kind of evidence more convincing than his own testimony. After the publication of so decisive a record, further exposure of the attempts which have sometimes been made to rob Dr. Black of his great and well-earned glory is wholly superfluous.

Priestley, who, in the year 1774, had effected by far the most remarkable and brilliant of his numerous discoveries, (that, viz. of oxygen gas), came in 1780 to Birmingham; where he afterwards usually resided, till driven away from that place in 1791, by the violence of a riotous mob, under the influence of religious and political exasperation. During the whole of his stay in that neighbourhood, which has been well described as at that period "a region of rare talents," he was on terms of habitual and friendly intercourse with Mr. Watt, frequently conversing with him on those scientific subjects which were of the greatest interest to them both; and we find him publicly and repeatedly acknowledging the pleasure he derived from such congenial society.*

It is impossible to conceive a more complete contrast than was presented by the mode of philosophising adopted by Black and Priestley respectively. The one, calm and reflective, conducted his experiments often with such simple apparatus as came readiest to his hand, but always with studied neatness, accuracy, and success; carefully watching every step of the well-considered process, and deducing, with all the force of exact demonstration, either the overthrow of some long-settled belief, or the description of a new substance, or the establishment on solid foundations of a theory altogether unsuspected by any other inquirer; his conclusions being as much distinguished for their originality, beauty, and usefulness, as any thing to be found in the whole history of inductive research. The other, with warm zeal and untiring perseverance, but with little idea of order, and an imperfect acquaintance with the true first principles of science, contrived experiments of infinite number and variety, observed them with lively interest, and often with a just perception; and minutely recorded the smallest particulars, which in their progress he noticed, if not always for his own advantage, yet certainly for the great benefit of others. But to the higher objects of philosophical inquiry and generalisation, he was little accustomed to apply the many great and luminous truths which he was the first to make known; and in more than one instance he even plunged deep into error, which some of his contemporaries, neither better informed on other points, nor gifted with superior powers of observation, were able to avoid. It is curious to find his well-known candour thus expressing his own views of the manner in which scientific research ought to be conducted, at a period nearly twenty years after he had received the Copley medal for his inquiries into several kinds of air, and had, almost at the same time, completed his grand and undisputed discovery of oxygen gas:—

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* 'Philosophical Transactions,' 1783, p. 416.

"I do not think it at all degrading to the business of "experimental philosophy, to compare it, as I often do, to "the diversion of *hunting*, where it sometimes happens that "those who have beat the ground the most, and are consequently the best acquainted with it, weary themselves "without starting any game, when it may fall in the way of "a mere passenger; so that there is but little room for "boasting in the most successful termination of the chase."* His metaphor reminds us of the jocose observation, said to have been addressed by Sir Isaac Newton to Dr. Barrow, who complained that he had occupied all the ground of new discovery:—"Beat the bushes: there is still plenty of game to "be raised."† But the proceedings of the other two great experimental inquirers whom we have named, were nothing like this; and we may perhaps question the propriety of applying language which conveys the idea of something vague, and even fortuitous, to that system which Bacon first illustriously taught, and which Black and Watt so worthily exemplified; by which the present age has been guided to very many of the more remote and occult parts of nature, with the same certainty and safety, with which the compass has directed the course of navigation to the discovery of new regions of the globe.

It cannot, however, be said that Priestley either derived small amusement from his quest of the game to which he alludes, or failed of brilliant success in that exciting chase, which he followed with enthusiastic ardour. It is equally true that he greatly contributed to its popularity with others. But though he could not fairly be called uncertain in his aim, he occasionally abandoned the main pursuit to follow some deceptive appearance in another track; and had often to submit, which he always did with perfect frankness and good-nature, to see his competitors triumph where he himself had failed. No more apposite or memorable instance of the truth of these remarks could be found, than in the discovery of which we are about to recount the history; where he stedfastly opposed a theory which was in great measure founded on one of his own experiments, but in which, even after it had received the most ample confirmation from the results of further inquiry, and had been adopted by nearly all the most eminent chemists of the day, he never could be induced to believe.*

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* See the Preface to his Abridgement of the 'Experiments on Air,' in three vols. 1790, p. 21.

† 'Works of Sir Humphry Davy,' edited by his Brother, vol. vii. p. 124.

Before proceeding to the history of the manner in which Mr. Watt was more immediately led to form and state in writing, his conclusions respecting the composition of water, which had previously always been looked upon as an *element* or simple substance, it is proper that we should shortly relate the steps which had been taken, before the year 1783, towards a more accurate knowledge of its real nature.

The first observation of the moisture which is formed when inflammable air or hydrogen gas is burnt in common air, was made by M. Macquer, an excellent French physician and chemist, whose good sense and judicious experiments rendered great service to science, at a time when few minds had as yet shaken off any of the fetters of the old philosophy. In that edition of his '*Dictionnaire de Chimie*' which was published in 1778, and of which his translator, Mr. Keir, says, that it had been much esteemed, and had perhaps contributed more to the diffusion of chemical knowledge than any other book, (and which, as well as its author, was always spoken of by Dr. Black with the greatest respect), he details, under the article 'Inflammable Gas,' many experiments on its combustion, which were made in 1776-7, and in which he was assisted by M. Sigaud de Lafond. "I assured myself "also," he says, "by placing a saucer of white porcelain in "the flame of inflammable gas burning tranquilly at the ori"fice of a bottle, that the flame is not accompanied by any "fuliginous smoke; for that part of the saucer which the "flame licked, remained perfectly white; it was only moist"ened by small drops of a liquor as clear as water, and

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* Among the latest of his publications was 'The Doctrine of 'Phlogiston Established, and that 'of the Decomposition of Water 'Refuted.' Northumberland, 1800.

"which, in fact, appeared to us to be only pure water."* The phenomenon was certainly a remarkable one, and it observation appears now, as it did to Lavoisier in 1783,† t have nearly approximated to a most interesting inqui which might, indeed, have ended in the discovery afterw so famous. But Macquer drew no conclusion from it, to no further notice of it, and seems not even to have haz a speculation on its cause.

He also mentions the combustion of mixtures bot inflammable gas and common air, and of inflammable and dephlogisticated air or oxygen gas; and describe explosion by which it was in both cases attended; that however, very much more violent in the latter case t the former. He seems to have fired the airs in glass but although on one occasion he speaks of having do close vessels, it is evident from his further account experiment, that the vessel employed had a narrow to which a lighted match was applied.

Volta, in a letter dated 10th December, 1776, printed in Dr. Priestley's third volume,‡ says, that fired inflammable air by the simple electric spark.

The next considerable step in the progress tow grand discovery, was made by an English chemist a sophical lecturer, Mr. Warltire; whose mode of c his experiments on the combustion of gases was high able to his ingenuity. He fired a mixture of com inflammable airs in a close metal flask or globe, by tric spark; and, his object being to ascertain "wh "was heavy or not," he says, "I always accurately "the flask of common air, then found the difference "after the inflammable air had been introduced, tha "be certain I had confined the proper proportion "The electric spark having passed through them "became hot, and was cooled by exposing it to th

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[*] 'Dictionnaire de Chymie,' tom. ii., p. 314; ed. Neuchâtel, 1789.

[†] Lavoisier, 'Mémoires de l'Académie' for 1781, printed in 1784, p. 469.

[‡] Priestley's 'Experin '&c.,' 1781, vol. iii., p. 3

" air of the room; it was then hung up again to the balance." Mr. Warltire adds, that in his experiments of this sort, he always found a small loss of weight, but not constantly the same; the vessel held three wine pints, and weighed fourteen ounces, and the average loss which he thought he detected, was only two grains.

These experiments are detailed in a letter dated Birmingham, 18th April, 1781, which was addressed to Dr. Priestley, and published by him in the appendix to the second volume of his 'Experiments and Observations relating to various 'branches of Natural Philosophy; with a continuation of the 'Observations on Air;' printed at Birmingham in 1781.*

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* Mr. Warltire's letter is given by Dr. Priestley as follows:—

" *A letter from Mr. John Warltire,*
" *Lecturer in Natural Philosophy,*
" *on the firing of inflammable air in*
" *close vessels.*

" Birmingham, *18th April,* 1781.

" Sir,—I had long entertained an " opinion that it might be deter- " mined whether heat is heavy or " not, by firing inflammable air, " mixed with common air, and ap- " plying them to a nice balance; but " as I conceived the danger of pass- " ing the electric spark through so " combustible a mixture in a close " vessel to be greater than it is, I " was deterred from making the ex- " periment, till, being encouraged by " you, I procured a copper ball, or " flask, which holds three wine pints, " the weight 14 oz., with a screw " stopper adapted to it, and began " with small quantities of inflam- " mable and large quantities of com- " mon air, which were fired without " the least danger.

" I then increased the bulk of the " inflammable air to half that of the " common air, which, when fired, " made the flask very warm to my " hand; and every time I applied a " long glass tube, fastened to the " pipe of a pair of bellows, to blow " the phlogisticated air out of the " flask, I observed a smoke escape " along with it. I also fired the air " when the flask was under water, " and did not observe anything escape " when I perceived the heat against " my hand with which I kept the " ball from rising. When the stopper " was unscrewed, the external air " always rushed into the vessel con- " taining the phlogisticated air with " some violence.

" The method I usually practise to " mix the airs in any proportion, is " accurately to fill a measure with " inflammable air, and rest it in a " tub, with its rim barely under " water, hanging over the edge of a " shelf, so far as to admit one leg of " an inverted syphon, the other leg " being closed, but afterwards opened, " and the copper flask inverted upon " it, but closed with its stopper when " the measure of air has been plunged " under water, to force it out through " the syphon. I have sometimes ex- " hausted the common air to admit " the inflammable air into the flask, " but I do not find that that cir- " cumstance produces any difference " in the result of the main experi- " ment.

" My next object was to adjust the " balance in such a manner as that " I could always be certain to weigh " to less than a grain when it was " loaded with the flask and its coun- " terpoise, and I constantly examined " it at the beginning and end of " every experiment. The apparatus " being adjusted, I proceeded to " make the experiment I had in view, " and always accurately balanced the " flask of common air, then found " the difference of weight after the

From the same letter it appears, that Priestley was th
to fire air in a close *glass* vessel, and to observe a dep
water; but that Warltire, on repeating the same expe
obtained the same result. "I have fired air in *glass* v
says Mr. Warltire, "since I saw you venture to do

"inflammable air was introduced, "that I might be certain I had confined the proper proportion of each, "the electric spark having passed "through them the flask became hot, "and was cooled by exposing it to "the common air of the room; it "was then hung up again to the "balance, and a loss of weight was "always found, but not constantly "the same; upon an average it was "about two grains.

"I have fired air in *glass* vessels "since I saw you venture to do it, "and have observed, as you did, that "though the glass was clean and dry "before, yet, after firing the air, it "became dewy, and was lined with a "sooty substance.

"If you think these experiments "worth communicating to your philosophical acquaintance, it may be "depended upon that the circumstances appeared to me as I have "represented them, whatever they "may be found to prove.

"I am, with great esteem,
"Your humble servant,
"JOHN WARLTIRE."

On this letter Dr. Priestley makes the following remarks:—

"The preceding article, though "coming too late to be printed together with the rest of the volume, "and to be noticed in the contents of "it, I have thought proper to insert "on account of the remarkable facts "it exhibits.

"Dr. Withering and myself were "present when the mixture of common air and inflammable air was "fired repeatedly in the close copper "vessel, and we observed that, notwithstanding all the precautions we "could think of, the vessel certainly "weighed less after the explosion "than it had done before. I do not "think, however, that so very bold "an opinion as that of the latent "heat of bodies contributing to their

"weight, should be receive
"more experiments, and
"a still larger scale. If
"firmed, it will no doubt
"to be a fact of a very
"nature, and will do t
"honour to the sagaci
"Warltire.

"I must add, that the
"saw the *moisture* on
"the close glass vessel.
"afterwards fired the
"air, he said that it
"opinion he had long
"viz., that common ai
"moisture when it is p
"With me it was a me
"periment, made to en
"philosophical friend
"formed themselves i
"society, of which th
"me the honour to ma
"ber.

"After we had fire
"of *common* and inflan
"did the same with d
"and inflammable air
"in this case, the lig
"more intense, and t
"greater, the explosio
"violent, but that a gl
"an inch in diamete
"ceeding one tenth
"thickness, bore it w
"Nor shall we wonder
"we consider that th
"air by heat does not
"or five times its bulk.
"however, from this ex
"little is to be expe
"firing of inflammabl
"parison with the ef
"powder; besides, th
"of inflammable air, t
"diminution of the
"whereas in the firing
"there is a producti
PRIESTLEY'S '*Experime*
'*vations*,' &c. Birmi
Vol. ii. p. *395.

" have observed, as you did, that though the glass was clean " and dry before, yet after firing the air, it became dewy, and " was lined with a sooty substance." Dr. Priestley adds, that Mr. Warltire, " the moment he saw the moisture on the " inside of the close glass vessel in which I afterwards fired " the inflammable air, said that it confirmed an opinion he " had long entertained, viz., that common air deposits its " moisture when phlogisticated;" both inquirers being evidently impressed with the belief that the dew was nothing else than the mechanical deposit of the moisture dispersed in common air.

It is remarkable enough, as an instance of the confusion which the least inattention must introduce into the history of such discoveries, and of the consequent importance of exact accuracy as to all their most minute particulars, that Mr. Watt inadvertently stated* that he believed Mr. Cavendish was the first who observed the dewy deposit; thereby assigning to him too much merit in place of too little. In that error, he has been followed by Cuvier, who says that "M. " Cavendish observa le premier qu'il se manifestoit de l'eau " dans cette combustion." † Mr. Cavendish ‡ expressly states Mr. Warltire to have observed it. Mr. Warltire § states Dr. Priestley to have observed it; while, ultimately, the mere observation of the moisture must be referred to Macquer, who also first considered it to be pure water.‖ But this point may be said to have excited no controversy, which has been limited to the question, who first explained the real cause of the formation of the moisture, by drawing and stating the conclusion that water is composed of two gases, which unite in the process of their combustion or explosion. To that question, accordingly, we shall now confine our attention, and see who was in point of fact the first to make public that theory, after having formed it altogether independently of the ideas of others.

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* See his Note, 'Phil. Trans.' for 1784, p. 332.—It is proper, however, to observe, that the note is not in Mr. Watt's original draft, nor in the press copy of the letter in his own writing, sent to Mr. De Luc, of 26th November, 1783; but is added at the bottom in pencil, in his own hand.

† 'Rapport Historique.'

‡ 'Phil. Trans.' 1784, pp. 126, 127.

§ In his letter, cited above.

‖ 'Dictionnaire de Chymie;' 'Mémoires de l'Académie' for 1781, p. 489; Arago, 'Eloge of Watt,' p. 98; ante, p. 313.

On the publication of Dr. Priestley's work in 1781, Mr. Cavendish proceeded in July of that year, and at subsequent times, to examine Mr. Warltire's experiment, (the object of which, it will be remembered, was to determine whether heat was ponderable), frequently repeating it, with changes in some parts of the apparatus, and in the mode of preparation of the airs employed. He fired mixtures both of common and inflammable air, and of inflammable and dephlogisticated air, varying the proportions of each; and, as was to be expected, not uniformly obtaining quite the same results. For, although he always observed, as Priestley and Warltire had done before him, that a dew was deposited, or, as he calls it, *condensed*, on the sides of the vessel in which the airs were fired, and though he applied more accurate measurement to the airs, and some tests to the "liquor condensed," he sometimes observed a slight loss of weight, sometimes none at all. In one instance, he found that "the weight seemed "to be diminished two-tenths on firing, and one-tenth more "on standing." *

Mr. Cavendish's journal, or collection of laboratory notes, in which the details of all these experiments were entered, has been preserved among his papers. The whole of those papers were accurately examined, his Grace the late Duke of Devonshire having granted permission, for the purpose of ascertaining whether any of them contained anything indicative of the dates of Mr. Cavendish's *conclusions*, respecting the theory of the formation of water by the combustion of hydrogen and oxygen gases; but Mr. Charles Hatchett "could "not find anything in them which referred to any date con"nected with the time when Mr. Cavendish probably first "conceived his theory;" † and another gentleman, Mr. Hudson, in whose hands the papers had been placed by the Duke of Devonshire, and who minutely investigated them with every wish to discover some support to the claims which had been put forth on behalf of Mr. Cavendish, said, "I do not "find in these journals of the experiments anything more "than the simple statement of the facts, without any casual "mention of theoretical opinions."[*] This material fact has since been placed beyond the possibility of doubt, by the publication of the journal in question; in the whole course of which Mr. Cavendish does not make a single inquiry into the cause of the appearance of the water, nor indicate the most remote suspicion of its real origin; never using any expressions which could imply an union of the two airs, or which are inconsistent with the notion which Warltire and Priestley had entertained, of a mere mechanical deposit of the water. We are fully borne out in this assertion by the opinion of Lord Brougham, who says, "I must add, having "read the full publication with fac-similes, Mr. Harcourt[†] has "now clearly proved one thing, and it is really of some importance. He has made it appear that in all Mr. Cavendish's diaries, and notes of his experiments, not an intimation occurs of the composition of water having been inferred "by him from those experiments earlier than Mr. Watt's "paper of Spring 1783."[‡]

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* MS. Journal.

† Letter to Mr. James Watt, junr., 16th April, 1835.

This fact further receives great confirmation from all that Mr. Cavendish has himself stated on the subject. His Paper, in which his conclusions are contained, was not read to the Royal Society till the 15th of January, 1784; and although in 1784, when the 'Philosophical Transactions' for that year were printed, he said that his experiments, (made in 1781), had been mentioned to Dr. Priestley, he does not name the precise time, nor even the year, when the experiments were so communicated. He does not say that any conclusion was, along with them, mentioned or even hinted at. He does not even say at what time he himself first drew any conclusion on the matter. But in a continuation of the same passage he says, "during the last summer, [1783], also, a

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[*] Letter to Mr. Hatchett, 15th April, 1835.

[†] See below, pp. 370-374.

[‡] 'Lives of Men of Letters and 'Science,' vol. i. p. 401.

" friend of mine gave some account of them to M. Lav
" as well as of the conclusion drawn from them, that deph
" gisticated air is only water deprived of phlogiston." T
passage was not contained in Mr. Cavendish's paper, as
ginally written, presented, and read to the Society; and
was afterwards added, not in Mr. Cavendish's handwri
but in that of Dr. (afterwards Sir Charles) Blagden, who
the friend referred to. As, however, it was printed in
body of the paper, without any explanation as to its sep
authorship, and, of course, with the knowledge and app
of Mr. Cavendish, that gentleman is to be held as making
statement contained in it, and the whole passage mu
taken as part of his paper.

And, (what is a most material proof of Mr. Cavendish
having made any communication of the theory), Dr. Prie
while, in his paper dated 21st April, 1783, and read 26th
of the same year, he alludes to one experiment of Mr. Cav
as being known to him, says not a word of any theory
that gentleman had founded upon it; but, on the c
was in evident ignorance of any conclusion such as th
Mr. Cavendish, nearly a year later, communicate
Royal Society. "It is clear," says Lavoisier,* "
" Priestley has formed water without suspecting it."
presently be seen that Dr. Priestley's first intelligen
idea being entertained that water is a compound b
from Mr. Watt; and was received not only with su
being entirely novel, but also with incredulity, as b
erroneous. The real state of the case is very well
by him in his paper, read 24th February, 1785, ar
in the 'Philosophical Transactions' for that year, whe
" Mr. Watt concluded from some experiments of wh
" an account to the Society, and also from some ob
" of his own, that water consists of dephlogisticate
" flammable air, in which Mr. Cavendish and M.
" *concur* with him." †

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* 'Mémoires de l'Académie' for 1781, p. 479.
† 'Phil. Trans.' for 1785, p. 280.

There is thus no statement put on record by Mr. Cavendish, so far as we have yet gone, of his conclusions having been either drawn by himself, or made known to a single human being, previous to the summer of 1783; while the only intimation to be derived from the printed papers in the Philosophical Transactions, of his having drawn his conclusions at even so early a period, is contained in the above passage, which was written by Blagden, interpolated after the paper had been read in January, 1784, and not till then adopted by Cavendish.

It is, further, apparent from the very title of his paper, '*Experiments on Air*,' that the composition of water was not the principal object to which Mr. Cavendish's attention had been directed. In this respect, his paper presents an obvious contrast to that of Mr. Watt, which bears the much more unequivocal title of 'Thoughts *on the Constituent Parts of* '*Water*, and of Dephlogisticated Air;' and of which the great object is to maintain that doctrine of the composition of water which is distinctly stated in its outset.

Moreover, some of the expressions used by Mr. Cavendish in further treating of the subject, are marked by no small ambiguity, and even inconsistency; for his theory is thus expressed in his own paper:—"From what has been said there "seems the utmost reason to think, that dephlogisticated air "is only water deprived of its phlogiston, and that inflam"mable air, as was before said, is either phlogisticated water, "or else pure phlogiston; but in all probability the former." Now, besides the strange supposition as to inflammable air being phlogisticated water, which shows that Mr. Cavendish had then no very clear ideas on the subject of water being composed of oxygen and hydrogen, it is evident that he here omits entirely the consideration of latent heat; an omission which he even attempts to justify in one of the passages interpolated by Blagden.* But it is well known to every one acquainted with the first principles of chemical science, even as it was taught in the days of Black, and it was indisputably familiar to Mr. Watt, that no aëriform fluid can be converted into a liquid, nor any liquid into a solid, without the evolution of heat, previously latent. This essential part of the process, Mr. Cavendish's theory does not embrace. But without it, no theory on the subject can be complete.

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* 'Phil. Trans.,' p. 140.

It will presently be seen, that Mr. Watt's theory took fully into account this most important principle, without which, no conversion from the aëriform to the liquid state can possibly take place; and without which, therefore, Mr. Cavendish's theory was quite inadequate to explain the facts observed.

We have the authority of one of the best informed practical and theoretical chemists of this country for declaring, that "ideas exactly similar to those of Mr. Watt are entertained "by the most distinguished philosophers of the present day." "Dr. Black," says Professor Graham of University College, "made it appear probable, that metals owe their malleability "and ductility to a quantity of latent heat combined with "them." * And the learned Professor carries the same doctrine further; where, in referring to change in the physical condition and crystalline configuration of bodies, without any alteration in their ponderable constituents, he says,— "The loss of heat observed will afford all the explanation "necessary, if heat be admitted as a constituent of bodies, "equally essential as their ponderable elements." † This may serve as another illustration of the masterly grasp of Mr. Watt's comprehensive mind, which could so early foresee all that subsequent inquiry has fully confirmed.

M. Lavoisier, in his celebrated Memoir, admits that a partial communication was made by Blagden, to him and some other members of the French Academy, when, on the 24th of June, 1783, along with M. La Place, he tried the experiment which they reported to the Academy on the following day. "He informed us," says Lavoisier, "that Mr. Cavendish "had already attempted to burn inflammable air in close "vessels, and that he had obtained a very sensible quantity of "water." He thus confines the extent of the communication

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* 'Elements of Chemistry,' p. 42.

† Ibid., p. 154.

within very narrow limits; for neither the experiment nor the result, as thus reported, was anything more than had been effected by Warltire and Priestley. Evidently he did not intend to admit that he knew of any *conclusion*, as to the real origin of the water, having been drawn by Cavendish; for in a subsequent part of the same memoir, he takes to his coadjutor and himself the credit of drawing such conclusion:—" we did not hesitate to conclude from it, that water is not " a simple substance, and that it is composed, weight for " weight, of inflammable air, and of vital air." He adds also, that they were then ignorant, and did not learn for some days, that M. Monge was occupied on the same subject.

It may be observed in passing, that as compared with Lavoisier and Cavendish, sufficient justice does not appear to have been done by writers on this subject, to the valuable labours of Monge. It is true, that when we consider the whole contents of his paper, which includes some deductions both hesitating and obscure, and even, so far as we can judge, incorrect; and recollect the comparatively late period at which it was first given to the world, in the Memoirs of the Academy, we find it impossible, without showing an undue excess of favour to his memory, to rank him, in respect either of the precision, or of the early date of his conclusions, along with any of the other three great philosophers who have been candidates, in either country, for the credit of the discovery. But his experiments, performed in the laboratory of the School at Mézières, were on a great scale; and are admitted, by Lavoisier and Meusnier,* to have been conducted with a very exact apparatus, and the most scrupulous attention. They are described in his paper in the Memoirs of the Academy for 1783, published in 1786; it is not stated when that paper was read, but a note mentions that they were made in June and July, and repeated in October, 1783, in ignorance of those of Cavendish in England, which were on a smaller scale, and of those of Lavoisier and La Place at Paris, which were made with an apparatus not fitted to attain so

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* 'Mémoires de l'Académie' for 1781, pp. 269, 270.

great exactness. Lavoisier and Monge thus declare
mutual ignorance of each other's proceedings: but Mon
never been accused, and may safely be acquitted, wh
other has been frequently, and with too much justic
victed, of concealing previous knowledge of other me
ceedings, in order to increase the estimated amount
own merits. Of Lavoisier, indeed, it has been sai
equal severity and justice, by an ingenious author and
lent chemist, "He has done sufficient, and been prais
" ciently for what he has done, to satisfy a mind th
" avaricious of fame ; he is deservedly placed in the fi
" among the philosophers of his day; and he ough
" have thrown a shade over his well-earned reputa
" claiming for himself the honour of those discover
" he had learned from another." *

The want of any date for either the authorshi
reading of M. Monge's paper, between the end of
1783, in which his experiments were made, and th
1786 in which it was published, leaves us in doubt
far he may have profited by the lights which we
that interval thrown upon the subject. Certainly
as there given, are very similar to those of Mr. W
of April, 1783, hereafter to be particularly noticed
" lows," says Monge, " from this experiment, th
" detonate inflammable gas and dephlogisticated
" considered as pure, we obtain no other result
" water, the matter of heat, and that of light." E
clusions, as further explained in the same pape
clear and decided than Mr. Watt's, or than those c
and Cavendish ; for he hesitates whether to consid
not a simple substance, or fire as a compound
encumbered with the uncertainty of an alternati
—either, of different substances being held in solu
fluid of fire considered as a common solvent, and
to produce water ; or else, of the two gases being
water in different elastic fluids, which quit the wate

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* Appendix to 'Memoirs of Priestley,' 1806, p. 25

in solution, in order to combine and form the fluid of fire and light, which escapes through the sides of the vessel in which the detonation takes place.

Lavoisier's paper having been in part read in November, 1783, was afterwards published with additions, which are not specifically distinguished from the original memoir, but are said to refer to the labour undertaken in common with M. Meusnier relative to the same subject. The volume in which it appears was published in 1784, and is known in the series of the '*Mémoires de l'Académie*' as that for 1781. It arrived in this country after Mr. Cavendish's paper had been read on 15th January, 1784, but before it was published in that year; and it is alluded to in another addition to Mr. Cavendish's paper, which was unquestionably made after its arrival in England, and in which the theory of the composition of water is more clearly stated than it had been by him previous to the enunciation and exposition of it by the enlightened French chemist.* A point of internal evidence that seems to fix within very narrow bounds the period at which that volume of the French Memoirs was printed, is, that Lavoisier therein speaks of Blagden as "*aujourd'hui Secrétaire de la* "*Société Royale de Londres*;" an office to which he was not appointed till the 5th of May, 1784.

Now, there can be little doubt, that the passage already cited, in which Blagden, in his own hand, but in Cavendish's name, detailed his communication to Lavoisier, was written to supply the imperfect admission of the French author, and to prevent those inferences as to priority of the theory, which otherwise might have been drawn in favour of Lavoisier. Considering the object thus manifestly in view, here, if anywhere, we ought to look for an explicit statement of the earliest date at which Mr. Cavendish's theory could be said to have been formed, which, at that time, there was no difficulty in ascertaining, and there could have been little in establishing; and we are fairly entitled to hold, that the earliest date consistent with the fact would be assigned, if not by the author of the paper, at least by his zealous and assiduous friend who is so much mixed up with the transaction. All this we say on the supposition, that the question as to priority had arisen merely between Lavoisier and Cavendish: for that is the whole length that our statement has as yet gone. We shall presently see whether other circumstances had not in the meantime arisen, which called still more loudly for that full, clear, and precise declaration which was to have been expected; and which was absolutely indispensable, in order to authenticate for the theory which Mr. Cavendish stated to the Royal Society on the 15th January, 1784, an earlier date than its publication on that day could ensure.

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* 'Phil. Trans.' for 1784, pp. 150-153.

CHAPTER XXI.

MR. WATT'S EXAMINATION OF DR. PRIESTLEY'S EXPERIMENTS IN MARCH AND APRIL, 1783 — HIS CONCLUSIONS AS TO THE COMPOSITION OF WATER — HIS LETTER TO DR. PRIESTLEY — DELAY IN READING IT BEFORE THE ROYAL SOCIETY — KNOWN TO CAVENDISH, BLAGDEN, AND LAVOISIER, IN 1783 — CAVENDISH'S PAPER OF JANUARY, 1784 — APPARENT PLAGIARISM — CURIOUS DOUBLE TYPOGRAPHICAL ERRORS — BLAGDEN'S LETTER TO CRELL, 1786.

MR. WATT, in whose neighbourhood Dr. Priestley says he had "the happiness to be situated," and with whom, as has been mentioned, he was on terms of friendship and frequent intercourse, had, previous to 1783, for many years entertained an opinion that air was a modification of water; and that, if steam could be made red-hot, so that all its latent heat should be converted into sensible heat, either the steam would be converted into permanent air, or some other change would take place in its constitution. "You may remember," he writes to Mr. Boulton,* "that I have often said, that if "water could be heated red-hot or something more, it would "probably be converted into some kind of air, because steam "would in that case have lost all its latent heat, and that it "would have been turned solely into sensible heat, and pro"bably a total change of the nature of the fluid would "ensue." And, so early as 13th December, 1782, he talks of processes "by which," he says, "I now believe air is gene"rated from water;" using the expression, "if this process "contains no deception, here is an effectual account of many "phenomena, *and one element dismissed from the list.*" †

Being thus, even at that time, prepared to expect that water was, in some way or other, convertible into air, he directed his attention to Dr. Priestley's experiment, which he thus accurately relates: "He puts dry dephlogisticated air "and dry inflammable air into a close vessel, and kindles "them by electricity. No air remains, at least if the two "were pure, but he finds on the sides of the vessel a quantity "of water equal in weight to the air employed."* In less than a month after he thus mentions his knowledge of that experiment, we find him writing to Dr. Black that he "believes he has found out the cause of the conversion of water "into air;"† and giving the very words in which, both on that day, and a few days later, he stated his conclusions in the letter to Dr. Priestley, which he desired might be read to the Royal Society:—"In the deflagration of the inflammable "and dephlogisticated airs, the airs unite with violence,—become red-hot,—and, on cooling, totally disappear. The "only fixed matter which remains, is *water*; and *water, light*, "and *heat*, are all the products. Are we not then authorised "to conclude, that water is composed of dephlogisticated and "inflammable air, or phlogiston, deprived of part of their "latent heat; and that dephlogisticated, or pure air, is composed of water deprived of its phlogiston, and united to "heat and light; and if light be only a modification of heat, "or a component part of phlogiston, then pure air consists of "water deprived of its phlogiston and of latent heat?" The same conclusions are given in other letters written nearly at the same time; but nowhere are they more clearly, briefly, or forcibly stated, than in that to Mr. Gilbert Hamilton of the 22nd of April, where, after a short enumeration of FACTS, beginning with the result of Dr. Priestley's experiment, follow these DEDUCTIONS.

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* 10th December, 1782.
† Mr. Watt to Mr. De Luc, 13th December, 1782.

"*Pure inflammable air is phlogiston itself.*

"*Dephlogisticated air is water deprived of its phlogiston, and* "*united to latent heat.*

"*Water is dephlogisticated air deprived of part of its latent* "*heat, and united to a large dose of phlogiston.*"

In writing to Mr. De Luc, four days afterwards, "These,"

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[*] To his brother-in-law, Mr. Gilbert Hamilton, 26th March, 1783.

[†] 21st April, 1783.

says Mr. Watt, "seem bold propositions, but I think they follow "from the present state of the experiments; and if I were "at leisure to write a book on the subject, I think I could "prove that no experiment hitherto made contradicts them, "and that the greater number of experiments affirm them."* To others of his correspondents he announced his theory in similar terms. To Mr. Smeaton, writing that he has "attempted to demolish two of the most ancient elements—air "and water;"† and to Mr. Fry, giving particular directions for the production of water and of [dephlogisticated] air:—"Dr. Priestley, as you observe, converts water into air, and "air into water, and I have found out the reason of all these "wonders, and also what air is made of, and what water is "made of; for they are not simple elements.—I have written "a paper on the subject, and sent it with Dr. Priestley's to "the Royal Society. It is too long to give you even an "abstract of it, but if you will forgive me the reasoning, I "will add the receipt below for making both these elements.

"*To make Water.*—

"R. Of pure air and of phlogiston Q.S., or if you wish to "be very exact, of pure air one part, of phlogiston, in a fluid "form, two parts, by measure. Put them into a strong glass "vessel, which admits of being shut quite close; mix them, "fire them with the electric spark; they will explode, and "throw out their elementary heat. Give that time to escape, "and you will find the water, (equal in weight to the air), "adhering to the sides of the vessel. Keep it in a phial close "corked for use.

"*To make Air.*—

"Take pure water Q.V., deprive it of its phlogiston by "any practicable method, add elementary heat Q.S. and distil. "You will obtain pure air, to be preserved as above."‡

It will be remembered, that in the letter to Mr. Hamilton he had shown his belief to be, that pure inflammable air and phlogiston were exactly synonymous; and it is very remarkable, that the proportions of the two gases which he directs to be fired, viz., of pure air one part, and of inflammable air two parts, by measure, are exactly those which chemists of the present day would employ.

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* 26th April, 1783. † 27th April, 1783. ‡ 28th April, 1783.

It appears from the letter to Dr. Black of the 21st of April, that Mr. Watt had, on that day, written his letter to Dr. Priestley, to be read by him to the Royal Society; but on the 26th he informs Mr. De Luc, that having observed some inaccuracies of style in that letter, he had removed them, and would send the Doctor a corrected copy in a day or two, which he accordingly did on the 28th; the corrected letter, (the same that was afterwards embodied verbatim in the letter to Mr. De Luc, printed in the Philosophical Transactions), being dated 26th April, and containing, almost at its very commencement, the following passages :—

“ The same ingenious philosopher mixed together certain
“ proportions of pure dry dephlogisticated air and of pure
“ dry inflammable air in a strong glass vessel, closely shut,
“ and then set them on fire by means of the electric spark.
“ The first effect was the appearance of red heat or inflam-
“ mation in the airs, which was soon followed by the glass
“ vessel becoming hot. The heat gradually pervaded the
“ glass, and was dissipated in the circumambient air, and as
“ the glass grew cool, a mist or visible vapour appeared in it,
“ which was condensed on the glass in the form of moisture
“ or dew. When the glass was cooled to the temperature of
“ the atmosphere, if the vessel was opened, with its mouth
“ immersed in water or mercury, so much of these liquids
“ entered, as was sufficient to fill the glass within about $\frac{1}{200}$th
“ part of its whole contents; and this small residuum may
“ safely be concluded to have been occasioned by some im-
“ purity in one or both kinds of air. The moisture adhering
“ to the glass, after these deflagrations, being wiped off, or
“ sucked up, by a small piece of sponge paper, first carefully
“ weighed, was found to be exactly, or very nearly, equal in
“ weight to the airs employed. In some experiments, but
“ not in all, a small quantity of a sooty-like matter was found

"adhering to the inside of the glass. The whole quantity of "sooty-like matter was too small to be an object of considera- "tion, particularly as it did not occur in all the experiments.

"Let us now consider what obviously happens in the case "of the deflagration of the inflammable and dephlogisticated "air. These two kinds of air unite with violence; they be- "come red-hot, and upon cooling totally disappear. When "the vessel is cooled a quantity of water is found in it equal "to the weight of the air employed. The water is then the "only remaining product of the process, and *water*, *light*, and "*heat* are all the products.

"*Are we not, then, authorised to conclude that water is com-* "*posed of dephlogisticated air and phlogiston, deprived of part* "*of their latent or elementary heat; that dephlogisticated or* "*pure air is composed of water deprived of its phlogiston, and* "*united to elementary heat and light; and that the latter are* "*contained in it in a latent state, so as not to be sensible to the* "*thermometer or to the eye; and if light be only a modification* "*of heat, or a circumstance attending it, or a component part of* "*the inflammable air, then pure or dephlogisticated air is com-* "*posed of water deprived of its phlogiston and united to ele-* "*mentary heat.*" *

In enclosing it, Mr. Watt adds, "As to myself, the more I "consider what I have said, I am the more satisfied with it, "as I find none of the facts repugnant."

Thus was announced for the first time, and with as much confidence as its eminent author thought it became any philosophical inquirer to feel, when prosecuting his researches into new departments of science, one of the most wonderful discoveries that are recorded in its annals. Of startling novelty, of admirable simplicity, it was destined to lead to consequences of an importance and grandeur perhaps unparalleled, except by those which have attended other exertions of the same inventive mind; or by those which, emanating from a kindred intellect, have immortalized the name of Newton. It has been justly termed the commencement of a new era, the dawn of a new day, in physical inquiry,—the real foundation of the new system of chemistry:—nay, even a discovery "perhaps of greater importance than any single fact which "human ingenuity has ascertained, either before or since."[*] The language in which this new and astonishing truth was expressed, though plain and perfectly unpretending, is so clear, precise, and just, that Mr. Cavendish,—accomplished chemist and perspicuous writer as he was,—could vary scarcely a single word of it, and that not for the better, when nine months later he made it public as his own: while M. Lavoisier, when *he too*, after it had been explained to him by Blagden, "*invented it himself, and read a paper on the subject* "*to the Royal Academy of Sciences*,"[†] altered only the terms which Mr. Watt had employed to express the two gases, viz. dephlogisticated air and inflammable air, or phlogiston, for their equivalents in his new nomenclature, viz. oxygen and hydrogen; their equivalents, that is to say, *in the sense in which Mr. Watt had used them.*

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* See the same passages, printed in the 'Philosophical Transactions' for 1784, pp. 331-333.

"To those," wrote Mr. James Watt, junr., in an interesting letter addressed to the author of this biography,[‡] "who may wish "to form a just appreciation of the circumstances in which this "correspondence took place, and of the merit that attaches "to my father for the discovery it records, I beg to state, in "the words of the great master of the English tongue, that "'it was written, not in the soft obscurities of retirement, or "'under the shelter of academick bowers; but amidst inconvenience and distraction, in sickness and in sorrow.' About "the beginning of the year, when the correspondence commences, he had returned from planning and superintending "the erection of his steam-engines, during a long sojourn in "Cornwall, where he had been much harassed by attempts "to pirate his improvements; and he was, through the

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[*] Dr. Thomas Young, in his review of Sir H. Davy's 'Elements of 'Chemical Philosophy.' Quarterly Review for Sept., 1812; reprinted in his Works, vol. i. p. 575. 1855.

[†] Mr. Watt to Mr. Fry, 15th May, 1784.

[‡] Dated Aston Hall, 5 February, 1846, and printed with Mr. Watt's 'Correspondence on his Discovery of 'the Theory of the Composition of 'Water,' published in the same year, pp. i. to xvi.

"greater part of the subsequent period, laboriously engaged "in making out drawings and descriptions for the long specifications of his three great patents for mechanical improvements and inventions, taken out in the years 1781, 1782, "and 1784, besides giving the constant attention necessary "to the concerns of a nascent manufactory, and himself "writing volumes of other letters on business, which alone "would have furnished full employment even to an industrious intellect. His mind had been greatly affected by his "unavoidable absence from the death-bed of his aged father; "and during the greater part of the time, I well remember "seeing him suffer under most acute sick head-aches, sitting "by the fire-side for hours together, with his head leaning "on his elbow, and scarcely able to give utterance to his "thoughts. It was unquestionably the busiest, as well as the "most anxious, period of his life, and fraught with the most "important results. I need not attempt to do justice to "them, for time has sanctioned the judgment of his contemporaries, who had done it already."

But,—to return to Mr. Watt's letter to Dr. Priestley, of 26th April, 1783,—"This letter," as is stated in Mr. Watt's Note published in the Philosophical Transactions, "Dr. Priestley received at London; and, after showing it to several "members of the Royal Society, he delivered it to Sir Joseph "Banks, the President, with a request that it might be read "at some of the public meetings of the Society."*

Had that been then done as requested, there cannot be a doubt in the mind of any one at all fitted to form an impartial opinion on the subject, that all possibility of controversy as to priority in the discovery must have been effectually prevented. It is true, that, judging from what actually occurred, it is difficult to say, even in that case, what use might have been made of the private perusal with which "several members of the Royal Society" were favoured. Lavoisier in France might even then have displayed that culpable want of a due acknowledgment of the aid he derived from others, which is so frequently to be deplored in the series of his most interesting, able, and elegant me Cavendish in England might still have failed to exe that generous liberality, which ought to have noticed eulogy, or, at least, to have named with exact justice, a sophical discoverer who had thus preceded him in the path. But both of those illustrious chemists would, events, have been in that case peremptorily debarre openly taking credit for either priority or novelty announcement of their theory; and it would have be harder for Cavendish or his friend even to have prete as for Lavoisier it is absolutely impossible to estab right to the claim of independent originality.

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* 'Philosophical Transactions,' 1784, p. 330.—Note.

But, as it happened, the public reading which had requested by Mr. Watt did not take place at th "Before that could be complied with," the note c "the author, having heard of Dr. Priestley's new "ments, begged that the reading might be delaye delay was, in some small measure, unfortunate for t tific renown of Mr. Watt; because competitors t stepped in, and sought to appropriate that discovery the world had not yet heard, and which, at that ti have been by all allowed to be honestly, solely, and ably his own. But the misfortune is infinitely inc we consider it as having led to doubts, seriously affe reputation of those competitors; as adding to the which one of them had, to the sorrow of science, justly incurred in similar matters; and as leaving fame of the other what must at least be termed a suspicion.

The new experiments alluded to in the note, Pries announced in these terms:—"Behold with surprise an "nation the figure of an apparatus that has utterl "your beautiful hypothesis,"* giving a rough sketch pen of the apparatus employed. But Mr. Watt imm and unhesitatingly replied, "I deny that your exp

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* Dr. Priestley to Mr. Watt, 29th April, 1783.

" ruins my hypothesis. It is not founded on so brittle a basis " as an earthen retort, nor on *its* converting water into air. " I founded it on the other facts, and was obliged to stretch " it a good deal before it would fit this experiment. * * * " I maintain my hypothesis until it shall be shown that the " water formed after the explosion of the pure and inflammable airs, has some other origin." * So to Mr. De Luc:— " I do not see Dr. Priestley's experiment in the same light " that he does. It does not disprove my theory. * * My " assertion was simply, that air," [*i. e.* dephlogisticated air, or oxygen, which was also commonly called vital air, pure air, or simply *air*,] " was water deprived of its phlogiston, and " united to heat, which I grounded on the decomposition of " air by inflammation with inflammable air, the residuum, or " product of which, is only water and heat."† Even when writing to Dr. Black that he had withdrawn his paper, he adds, " I have not given up my theory."‡

But he did withdraw, or rather reserve the public reading of his paper, till he should further examine the new experiments which were said to be hostile to the doctrine which it unfolded; and also, as he adds with his usual modesty, because he was " informed that that theory was considered too bold, " and not sufficiently supported by facts."§ " Mr. Watt " then wished," as it is more fully expressed in a work published shortly afterwards, " that the letter should not be read " at the public meeting of the Society, because he learned " that his theory was thought too bold, or that a substance " such as water, till then considered as of the nature of an " *element*, was there placed in the class of *compounds*." ‖ But the letter itself, after being read by many members, remained in the custody of the President till the day when it was read to the Society, 22nd April, 1784, as is well ascertained from Mr. Watt's letter to Blagden of 27th May, 1784.

On the upright and unsuspecting philosopher, whose diffidence of his own admirable judgment, and "respect for the "opinions of others where he thought they might merit it," had led him thus to delay what he calls "the first attempt "he had made to lay any thing before the public," a new and unpleasant light was destined soon to break. But in the meantime, having by additional experiments still further satisfied himself of the correctness of his theory, in which he had never been able to detect error, and the truth of which he now held to be abundantly confirmed, he proceeded, towards the end of November, tranquilly to occupy himself in preparing a more full statement of it, to be sent to his friend De Luc, for the purpose of being read to the Royal Society. By the 1st of December, however, we find that he had received accounts of an occurrence which appeared to stand much in need of explanation; and which, after that had been obtained, proved little to the credit of some of those concerned. "I was," he says, in writing to Mr. De Luc,* "at Dr. "Priestley's last night. He thinks, as I do, that Mr. Lavoi-"sier, having heard some imperfect account of the paper I "wrote in the Spring, has run away with the idea, and made "up a memoir hastily, without any satisfactory proofs. How "that may be, I cannot take on me to say; but if you will "read the 47th and 48th pages of Mr. De la Place's and his "Memoir on Heat, you will be convinced that they had no "such ideas then, as they speak clearly of the nitrous acid "being converted into air. I therefore put the query to you "of the propriety of sending my letter to pass through their "hands to be printed; for even if this theory is Mr. Lavoi-"sier's own, I am vain enough to think that he may get some "hints from my letter, which may enable him to make expe-"riments, and to improve his theory, and produce a memoir "to the Academy before my letter can be printed, which may "be so much superior as to eclipse my poor performance, and "sink it into utter oblivion; nay, worse, I may be condemned "as a plagiary, for I certainly cannot be heard in opposition "to an Academician and a Financier. * * But, after all,

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* Mr. Watt to Dr. Priestley, 2nd May, 1783.

† To Mr. De Luc, 18th May, 1783.

‡ To Dr. Black, 23rd June, 1783.

§ Mr. Watt to Sir Joseph Banks, 12th April, 1784.

‖ De Luc, 'Météorologie,' tom. ii., p. 216. 1786.

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* 30th November, 1783.

" I may be doing Mr. Lavoisier injustice. * * I see it, on " the one hand, so difficult to satisfy those nice chemists, " and, on the other hand, so difficult to be allowed even the " honour of the discovery, that I am nearly discouraged, " either from publishing at all, or trying any more experi- " ments; as it seems to be losing my labour and procuring " myself disquiet." " M. Lavoisier," he also writes, " has " read a memoir opening a theory very similar to mine on " the composition of water; indeed, so similar, that I cannot " help suspecting he has heard of the theory I ventured to " form on that subject, as I know that some notice of it was " sent to France." *

To this conjecture, Mr. Kirwan was able, in his reply, to add the most positive assurance. " M. Lavoisier," he writes, " certainly learned your theory from Dr. Blagden, who first " had it from Mr. Cavendish, and afterwards from your letter " to Dr. Priestley, which he heard read, and explained the " whole minutely to M. Lavoisier last July." [June.] †

The letter was, of course, well known to Dr. Priestley, who received it, perused it, and at once occupied himself in answering it, and to Sir Joseph Banks, in whose hands it long remained. But that it was also read by many other members of the Royal Society, though not then at a public meeting of the body, there cannot be any manner of doubt. For we have not only the direct statement of Mr. Watt to that effect, published in the Philosophical Transactions in 1784, under the direct superintendence of Dr. Blagden, and repeated by Mr. De Luc in 1786,‡ but we have Blagden admitting his own knowledge of the paper, both in the statement which he says he made to Lavoisier in June, and in his letter which Crell printed in 1786, of which we shall presently have much more to say. Mr. Kirwan's letter completes the demonstration of Blagden having acquired a minute knowledge of the paper, some time at least before he went to Paris, which was not later than the beginning of

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* To Mr. Kirwan, 1st December, 1783.

† Mr. Kirwan to Mr. Watt, 13th December, 1783.

‡ 'Météorologie,' vol. ii., p. 216.

June.* It also appears very probable, (as it was d
meant by Kirwan, and understood by Mr. Watt), that
first account of Mr. Watt's theory which Blagden
received, he had from Cavendish. For the words are, '
“ voisier learned *your theory* from Dr. Blagden, who first
“ *it* from Mr. Cavendish, and afterwards from your lett
“ Dr. Priestley, which he heard read.” The theory
spoken of is not said to have been one which had
formed by Cavendish, or which merely bore some r
blance, whether general or close, to that of Mr. Watt;
Mr. Watt's own theory alone that is spoken of;—the
that Blagden more closely studied when he read the
in which it was explained, but which he first appears to
heard of from Cavendish's report. Such is the only n
and obvious sense of Blagden's words, as reported by Ki
and, though it is by no means essential to our argum
insist upon it, they are almost incapable of any other
pretation. We are, however, perfectly justified in as
that *two* such theories, so novel and strange as to b
deemed incredible, could scarcely have come to any
science, or even any pretender to scientific knowled
from one discoverer and then from another, both wit
same month,—perhaps on the same day,—without
some observation on so marvellous a coincidence,—s
ther explanation—some particular inquiry, as to the t
manner of the theory being announced, or formed,
discoverer respectively. Still more strongly does thi
apply, from the circumstance of Blagden being well ac
with Cavendish's proceedings. If the theories had t
distinct, but if Mr. Watt's so much resembled anc
viously formed, as to be spoken of and treated as t
would Blagden have had no wonder to express, no di
ment to feel, at his patron having been both rivall
formation of it, and certainly anticipated in the a
ment? Would he have had no explanation to offer,

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[*] We know, from a private letter of Blagden's, that on the 11th of June he had been in Pari days.

ority to attempt to sustain,—no originality to claim for Mr. Cavendish, even if that gentleman was unwilling to do so for himself? We repeat it:—the only theory alluded to here, is, so far as appears, that which Mr. Watt conceived, and which he alone had as yet committed to writing. Such was evidently Mr. Watt's own view of the meaning of Mr. Kirwan's communication; and we are, however unwillingly, compelled to admit that the first part of the great engineer's reflections on the tidings sent by Kirwan may have been applicable in other quarters than that to which he then directed it. "You "see," he says, "from the above that it is possible for a philosopher to be disingenuous. For M. Lavoisier had heard "of my theory before he formed his, or before he tried the "experiment of burning dephlogisticated and inflammable "airs together, and saw the product was water."*

Mr. De Luc having gone to Paris in December, 1783, and there passed the month of January, 1784, returned to England in February, when his letters to Mr. Watt were resumed. In the meantime, on the 15th January, Mr. Cavendish had read to the Royal Society the first part of his celebrated 'Experi'ments on Air,' of which the second part was not read till the 2nd of June, 1785. In one of Mr. De Luc's letters, dated 1st March, 1784, he mentions that he had heard some particulars of the paper which Mr. Cavendish had read, but nothing concerning *the conclusions* stated in it as to the composition of water appears to have been then reported to him. The imperfect account which he thus received came from Dr. Blagden. As the paper, however, was said to have included a thorough examination of the combustion of the two airs, he requested Mr. Cavendish's permission to see it, which was granted.

The consternation into which he was thrown on perusing it for the first time is well depicted in the close of the same letter:—"Being at this point of my letter, I have received "Mr. Cavendish's paper, and have read it!! . . . . Ex"pect something that will astonish you as soon as I can write "to you. . . . Meanwhile, tell no one. . . . *In short,*

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* Mr. Watt to Mr. De Luc, 30th December, 1783.

" *he expounds and proves your system, word for word, and* " *makes no mention whatever of you.*"

The fact, however surprising, and whatever inferences may be drawn from it, was literally true. In the whole of that paper, as Mr. De Luc saw it, and as it had been read at the Royal Society, the learned chemist who had so carefully prepared it had never once named James Watt, whose theory on the same subject had become " known to all the active " members " of the same Royal Society for nearly nine months; had been announced and confirmed at Paris for nearly seven months, and was all the while minutely familiar to Blagden, the chosen friend and constant companion of Cavendish, professing to be engaged in the same pursuits with him, and who certainly was, as De Luc has elsewhere said, " informed of all his experiments, as well as of those of " Dr. Priestley, and of the ideas of Mr. Watt."

Mr. De Luc, in his letter of the 1st March, had promised an analysis of Cavendish's paper, and on the same day began a long transcript of its principal parts, which he finished on the 4th March, and sent to Mr. Watt in a letter, which showed that, on a further examination, his amazement had not subsided. Having endeavoured, in some degree, to defend Lavoisier and La Place from the charge of *le Plagiat*, he says—" But that which is, on the other hand, perfectly clear, " precise, astonishing, is the memoir of Mr. Cavendish. *Your* " *own terms, in your letter of April to Dr. Priestley, given as* " *something new, by some one who must have known that letter,* " *which was known to all the active members of the Royal* " *Society—to Dr. Blagden above all,* (for he said he had " spoken of it to Messrs. Lavoisier and La Place), who well " knew Mr. Cavendish's memoir, both before it was read to " the Royal Society, and at its reading, and who conversed " with me about it, as I told you in my last—me, whom he " knows to be your zealous friend." After strongly recommending caution, De Luc says—" It is yet possible that Mr. " Cavendish does not think he is pillaging you, however pro" bable it is that he does so;" giving as his reasons for desiring to entertain so charitable a hope, that Cavendish had not objected to let him peruse his paper, and also the character which both Cavendish and Blagden had previously maintained. The force of the first of these considerations is much diminished, when we remember, that the paper in question had already been made public to a great extent by being read at the Royal Society, and was, besides, soon to be printed in the Philosophical Transactions: so that there could be no possibility of keeping it secret, had that been desired. And the character of Mr. Cavendish was clearly no excuse for the entire suppression of Mr. Watt's name in his paper; a defect which was afterwards, in Blagden's interpolation, most inadequately remedied; and which must ever remain a reproach both to Cavendish and to his companion Blagden, whose early and intimate knowledge of Mr. Watt's letter to Priestley has been so completely proved.

In the very delicate and disagreeable circumstances which had thus occurred, Mr. De Luc suggested two modes of proceeding: the one, to suffer in silence the injustice which he could not but feel had been done, in which case he engaged to print the letters to Dr. Priestley and himself, with their dates, in a work he was then preparing; the other, to make the matter more public, by requesting Sir Joseph Banks to cause both the letters to be read to the Royal Society. In recommending the former, the too discreet philosopher used these words:—"I should almost advise it, considering that, "in your position of drawing from your discoveries practical "consequences for your fortune, you must avoid making "yourself *des jaloux*."

He had yet to learn the full extent of the manly virtue of his friend; who, while he declined to make any attack upon Mr. Cavendish, admitting, perhaps with a somewhat extravagant liberality, that it was "barely possible" that he might not have heard of his theory, still spoke in a strain of honest indignation of the plagiarism which he felt there was too much room to believe had been effected, of the wound which his scientific fame had been made to suffer, and of the hardship of being thus anticipated in the first attempt he had made to lay anything before the public. "As to what you

"say," he wrote, "about making myself *des jaloux*, tha
"would weigh little; for, were I convinced I had ha
"play, if I did not assert my right, it would either be
"contempt for the modicum of reputation which would
"from such a theory, from a conviction in my own mi
"I was their superior, or from an indolence that m
"more easy for me to bear wrongs, than to seek redre
"point of interest, so far as connected with mone
"would be no bar: for though I am dependent on th
"of the public, I am not on Mr. C. or his friends, a
"despise the united power of *the illustrious house of* C
"as Mr. Fox calls them. You may, perhaps, be sur
"find so much pride in my character. It does not s
"compatible with the diffidence that attends my c
"general. I am diffident, because I am seldom ce
"I am in the right, and because I pay respect to th
"of others, where I think they may merit it. At
"*me sens un peu blessé;* it seems hard, that i
"attempt I have made to lay any thing before th
"should be thus anticipated. It will make me ca
"I take the trouble of preparing any thing for th
"time." *

What followed may be very briefly told: "He
"intention of being in London in the ensuing we
"opinion, that the reading of his letter to the Ro
"will be the proper step to be taken. He accor
"there, waited upon the President of the Royal
"Joseph Banks, was received with all the courte
"feeling which distinguished that most honourab
"it was settled, that both the letter to Dr. Pries
"April, 1783, and that to Mr. De Luc of 26th
"1783, should be successively read. The forme
"on the 22nd, and the latter on the 29th Ap
and it is said by Sir Joseph Banks, that "bot

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* Mr. Watt to Mr, De Luc, 6th March, 1784.

† Note by Mr. James Watt, junr., added to Lord Brough Note. — See Translat 'Eloge,' p. 164.

" to meet with great approbation from large meetings of " Fellows." *

Both of the letters were ordered by the Committee of Papers to be printed, and it was arranged that the best form in which that could be done, in order to avoid repetition, was by incorporating the first with the second, which was accordingly the plan adopted; " but," as the note in the Philosophical Transactions bears, " to authenticate the date of the " author's ideas, the parts of it which are contained in the " present letter are marked with double commas."

Blagden became Secretary of the Royal Society on the 5th of May, 1784; and to him, in virtue of his office, was entrusted the superintendence of the printing of Mr. Watt's paper. In his letters on that subject, he appeared perfectly willing to attend with care to the publication; and in one of them offered, should Mr. Watt desire it, to send him the proof-sheets for correction. Mr. Watt, residing at a distance from town, declined his offer; a resolution which he had afterwards reason to regret; for the consequence has been, that in his paper, as it stands in the Philosophical Transactions, there is a very unfortunate *error of the press.* The date of the letter to Mr. De Luc, which we have just seen was 26th November, 1783, is there given as 26th November, 1784. It is true that the date of the *reading* of the paper is rightly given; it has also been lately discovered that the misprint is noticed in the errata at the end of the volume of the Philosophical Transactions in which it appears; and therefore that error might not always mislead: but, considering all that had previously occurred, it was of great importance that every date establishing Mr. Watt's priority should be accurately printed, and what we shall in this instance call carelessness, even if freed from blame, must on every account remain matter of regret.

But this is not all. Of Mr. Cavendish's paper there were a number of separate copies thrown off, which were widely circulated throughout Europe by himself and his friends, before the seventy-fourth volume of the Philosophical Transactions, in which it was to be contained, made its appearance. These also, it is presumed, had been printed under the superintendence of Dr. Blagden, and of Mr. Cavendish. They all bear on their title-page, that Mr. Cavendish's paper was "read at the Royal Society, January 15, 1783." Moreover, the true date, 1784, which is placed at the head of that paper as it stands in the Philosophical Transactions, is not given at all in those separate copies. We annex a fac-simile of the erroneous title-page, which, it must be admitted, is most highly suspicious, and, to say the least, far from creditable to the accuracy of Messrs. Cavendish and Blagden.

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* Sir Joseph Banks to Mr. Watt, 11th May, 1784.

It is said, on the strength of a draft of a letter reported to have been found among Cavendish's papers, that in one instance, more than a year afterwards, (when the error had already been propagated in most of the scientific Journals of the Continent, and when also the Philosophical Transactions with the true date of the reading of the paper had come into circulation), Mr. Cavendish desired that it might be corrected. We have no desire to take from him the credit of having done so, or intended to do so, in that instance, although no proof has been produced of such a letter having ever been actually sent by him, or received by any one else. But the error continued long afterwards to have its natural, unjust effect. For Cuvier, writing at the distance of four and twenty years from the circulation of the erroneous date, has distinctly said, "The experiment of Mr. Cavendish dates from 1781; "the reading of his Memoir, from January, 1783;" and he gives Cavendish the precedence over Lavoisier in their respective published memoirs, making the latter superior only in having discarded the hypothesis of phlogiston.* In his Eloge of Cavendish,† it is true, he alters 1783 to 1784, observing that three years had been occupied "in establish-"ing that great phenomenon;" but still his readers are left without the means of knowing which of the two dates is the

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* 'Rapport Historique,' 1808, p. 57.

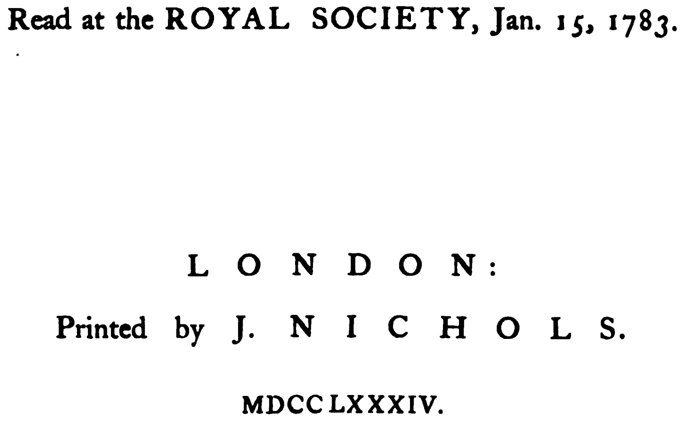
† 'Mémoires de l'Académie' for 1811, p. cxxxiii; and, in the separate edition of Cuvier's 'Eloges Historiques,' tome ii. p. 87.

EXPERIMENTS

ON

AIR.

By HENRY CAVENDISH, Eſq. F.R.S. and AS.



Read at the ROYAL SOCIETY, Jan. 15, 1783.

LONDON:

Printed by J. NICHOLS.

MDCCLXXXIV.

[Fac-simile of the erroneous Title-page prefixed to the separate copies of Mr. Cavendish's 'Experiments on Air,' read before the Royal Society, January 15, 1784.]

To face page 344.

right one. Numerous as are Cuvier's errors on such points, yet his illustrious name, and the charms of the diction in which he clothes the history of philosophy and philosophic men, have led him to be cited by many as a safe authority; and although those who themselves practise such inaccuracies with a fatal facility, may think lightly of their effect, this only the more deeply impresses us with the sacred obligation of scrupulously recording matters of fact in subjects of controversy, and makes us more sensible of the inestimable value of rigid accuracy.

Every one must admit, that after the series of events which we have now detailed,—after the zealous attempts to establish priority which had been made by two of the three great claimants for the honour of the discovery, and the public statement which had been put on record by the third, (which, being uncontradicted, might be deemed decisive), it was, truly, most unfortunate that any thing should occur which could give to any of the proceedings, even in appearance, a character not altogether consistent with justice. It was at least a piece of most singular negligence, on the part of the Secretary to the Royal Society who superintended the printing, that those papers should have been circulated with a double error in their dates; that the tendency, if not the effect, of both of the errors should have been, to take the priority from Watt, and to give it to Cavendish, the Secretary's intimate friend and patron; and that, of all the errors which the printer might have committed, he should have happened to select precisely those which were so well fitted to effect that object. When M. Arago exclaimed, after mentioning the same circumstance, "God forbid that I should, by these " remarks, intend to cast any imputation on the literary pro- " bity of those illustrious philosophers; they only prove that, " on the subject of discoveries, the strictest justice is all that " can be expected from a rival, or a competitor, however high " his reputation may already be,"* we must confess that he well deserves to receive credit for restraining, within the bounds of those moderate words, the expression of a strong and just indignation.

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* 'Eloge of Watt,' p. 106.

An additional argument certainly arises from the remarkable fact, that Cavendish appears never to have made any observation on Mr. Watt's chronological note, when it was printed with his paper by the Royal Society; nor ever to have confessed his knowledge of the real time at which Mr. Watt made either his first or his second communication, or of that at which he thus knew that his conclusions were drawn. But we have not yet done with either the history of the discovery, or the share which Dr. Blagden took in it as an auxiliary and historian. Finding that Lavoisier still maintained some claim, and seeing from the note appended to Mr. Watt's paper, and from the total want of any statement as to the chronology of Cavendish's conclusions, that Mr. Watt stood distinctly recorded as the first discoverer, notwithstanding the inexplicable awkwardness of the typographical errors, Blagden thought proper to write the letter to Dr. Lorenz Crell, printed two years later in his Journal, of which the following is a translation: *—

"I can certainly give you the best account of the little "dispute about the first discoverer of the artificial generation "of water, as I was the principal instrument through which "the first news of the discovery that had been already made "was communicated to Mr. Lavoisier. The following is a "short statement of the history:—

"In the Spring ('Frühjahr') of 1783, Mr. Cavendish "communicated to me and other members of the Royal "Society, his particular friends, the result of some experi"ments with which he had for a long time been occupied. "He showed us, that, out of them, he must draw the con"clusion, that dephlogisticated air was nothing else than "water deprived of its phlogiston; and, *vice versâ*, that water "was dephlogisticated air united with phlogiston. About the "same time ('um dieselbe Zeit') the news was brought to

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* The letter appears not to have been dated; but it was published in Crell's 'Chemische Annalen,' Helmstädt u. Leipzig, 1786, pp. 58-61.

" London, that Mr. Watt of Birmingham had been induced " by some observations, to form ('fassen') a similar opinion. " Soon after this ('bald darauf') I went to Paris, and in the " company of Mr. Lavoisier, and of some other members of " the Royal Academy of Sciences, I gave some account of " these new experiments, and of the opinions founded upon " them. They replied that they had already heard something of these experiments; and, particularly, that Dr. " Priestley had repeated them. They did not doubt, that in " such manner a considerable quantity of water might be " obtained; but they felt convinced that it did not come near " to the weight of the two species of air employed; on which " account it was not to be regarded as water formed or produced out of the two kinds of air, but was already contained in, and united with the airs, and deposited in their " combustion. This opinion was held by Mr. Lavoisier, as " well as by the rest of the gentlemen who conferred on the " subject; but, as the experiment itself appeared to them " very remarkable in all points of view, they unanimously " requested Mr. Lavoisier, who possessed all the necessary " preparations, ('Vorrichtungen'), to repeat the experiment " on a somewhat larger scale, as early as possible. This desire " he complied with on the 24th June, 1783, (as he relates in " the latest volume of the Paris Memoirs). From Mr. Lavoisier's own account of his experiment, it sufficiently " appears, that at that period he had not yet formed the " opinion, that water was composed of dephlogisticated and " inflammable airs; for he expected that a sort of acid would " be produced by their union. In general Mr. Lavoisier " cannot be convicted of having advanced any thing contrary " to truth; but it can still less be denied, that he concealed a " part of the truth. For he should have acknowledged that " I had, some days before, apprized him of Mr. Cavendish's " experiments; instead of which, the expression 'il nous " 'apprit,' gives rise to the idea that I had not informed him " earlier than that very day. In like manner Mr. Lavoisier " has passed over a very remarkable circumstance, namely, " that the experiment was made in consequence of what I

" had informed him of. He should likewise have stated in " his publication, not only that Mr. Cavendish had obtained " 'une quantité d'eau très sensible,' but that the water was " equal to the weight of the two airs added together. More- " over, he should have added, that I had made him ac- " quainted with Messrs. Cavendish and Watt's conclusions; " namely, that water, and not an acid or any other substance, " ('Wesen'), arose from the combustion of the inflammable " and dephlogisticated airs. But *those* conclusions opened " the way to Mr. Lavoisier's present theory, which perfectly " agrees with that of Mr. Cavendish; only that Mr. Lavoisier " accommodates it to his old theory, which banishes phlo- " giston. Mr. Monge's experiments, (of which Mr. Lavoisier " speaks as if made about the same time), were really not " made until pretty long, I believe at least two months, later " than Mr. Lavoisier's own, and were undertaken on receiving " information of them. The course of all this history will " clearly convince you, that Mr. Lavoisier, (instead of being " led to the discovery, by following up the experiments which " he and Mr. Bucquet had commenced in 1777), was induced " to institute again such experiments, solely by the account " he received from me, and of our English experiments; and " that he really discovered nothing but what had before been " pointed out to him to have been previously made out, and " demonstrated in England."

Now, before examining the history which this letter gives of the discovery, it is to be observed that it professes to have been written in order to give *the best account* of the dispute about *the first discoverer*. And from the relations in which Blagden stood to Cavendish, and the obligations he owed him, he cannot be suspected of under-stating any claims which he might have been able to establish for that gentleman to the possession of so great an honour.

Bearing this in mind, and taking the statement as we find it, an extraordinary fact which meets us at the outset is, that it does not contain any distinct allegation of Cavendish having been *the first discoverer;* although it does positively assert that he was prior to Lavoisier, and appears to aim at aving it understood that he was prior also to Mr. Watt. ven the time at which Cavendish is reported to have communicated to his friends of the Royal Society his experiments and their results, and "showed that out of them he must " draw the conclusion," is only noted in the most general way, as "in the Spring of 1783." But we know that Mr. Watt's conclusions, on the other hand, were actually formed, reduced to writing, (which Cavendish's confessedly were not), and known to many members of the Royal Society, also "in " the Spring of 1783;" and Blagden, though he was well aware of all these circumstances, and professes to give " the " best account," and was naturally desirous of gaining the credit of the priority for his patron, does not even state that *Cavendish's verbal communication* preceded his knowledge of *Mr. Watt's written conclusions.*

But further, no time has ever yet been stated, either by Cavendish or Blagden, at which the former really drew his conclusions; which are thus never heard of as having been even imagined by him till "the Spring of 1783;" and in the absence of all such assertion by either of those gentlemen, or by any one else who was acquainted with the circumstances, it is impossible, in common fairness to the other parties concerned, to attribute his conclusions to an earlier period than that which, however vaguely, is so assigned to them.

Again, if Mr. Cavendish, at the time of making his communication to his friends, was ignorant of Mr. Watt's conclusions, of which, even according to Blagden, " the news was " brought to London about the same time," why does not Blagden, in his claim of priority, make any assertion to that effect? Would he not have done so if he could, and is it not a perfectly fair inference from the fact of his not having done so, that he knew he could not?

If, on the contrary, Cavendish was then in the knowledge of Mr. Watt's conclusions, why did he not, in order to assert any claim for himself, not only to priority, but even to originality, mention in his verbal communication to his friends, that he had drawn his own conclusions, or rather, had seen " that he must draw them,"—for that is the more circuitous way in which Blagden puts it,—before he had heard of those of Mr. Watt, and independent of them?

Failing any statement of the time,—not during which he had been occupied with his experiments, for that proves nothing,—but at which he had first drawn the particular conclusion from them, that "dephlogisticated air is in reality "nothing but dephlogisticated water, or water deprived of its "phlogiston,"—he could claim no priority, except as against a discoverer, the date of whose discovery could be proved to be subsequent to that communication to his friends, the members of the Royal Society. But only a vague approximation being attempted to the date of his communication, and no better or earlier one being even suggested as that of his conclusions,—(and that, too, in "the best account" that could be given of his claims, published in his own lifetime, and written by one who well knew the necessity there was for the greatest possible minuteness and precision of chronological record),—and no later period being assigned as that of his knowledge of Mr. Watt's conclusions, the inference is both just and inevitable, that neither Cavendish, nor Blagden on his behalf, could establish any priority as against Mr. Watt.

It was comparatively an easy matter to assert it for one or both of the English philosophers as against Lavoisier, for that chemist, on his own showing, could not claim, even for his *experiment*, an earlier date than the 24th of June, 1783; and, had his been the only competition which Cavendish had to apprehend, "the Spring" might have been held a sufficient anticipation; when taken in connexion with what Blagden states, and Lavoisier partially admits, to have passed at Paris. Still, even in that case, Blagden's way of speaking must have appeared to all accurate inquirers very negligent, very unsuitable to the nicety of the subject, and very unfit for the purposes of careful scientific history.

But when the question concerns the conclusions of Mr. Watt, which had been stated not verbally, nor at an uncertain date, nor only to his own private and particular friends, but in writing, on the 21st and subsequent days of April, to many members and the President of the Royal Society; and which, before this letter of Blagden's was written, had been printed in the 'Philosophical Transactions,' under Blagden's immediate eye and sole superintendence, with a note emphatically and fully "authenticating the date of the author's ideas,"—it would be utterly absurd to found any claim, or even any argument in support of a claim, on an expression so indeterminate as that of "*the Spring.*"

Was it early in the Spring, or late in the Spring? Was it in February, or in March, or in April? We apprehend that neither Mr. Cavendish nor Dr. Blagden would have thanked us for the supposition that it might possibly have been *in May.* But "questions as to priority," says M. Arago, "may "depend"—not only on years, and on seasons, and on months—but "on weeks, on days, on hours, on minutes." In what week, on what day of the month, was the important disclosure made by Mr. Cavendish? To bring the matter to a short issue;—was it not after a certain letter, of date the 26th of April, 1783, had been received by Dr. Priestley at London, shown to "several members of the Royal Society," nay, *read and minutely studied by Dr. Blagden,* (for that is proved by his own admission to Kirwan), and then delivered to Sir Joseph Banks the President?

Blagden could not, surely, have so soon forgotten all the circumstances which attended so important a communication; he must at least have remembered whether, when it came from Mr. Cavendish, it was no longer graced with the freshness and interest of novelty; and whether it was not an echo of something else which had come to London and his ears "*about the same time.*" Of two theories so nearly identical, he surely could have recollected, without much difficult reflection, which he had heard first; the memory which was so retentive as to the proceedings at Paris, where Lavoisier was concerned, could not well have been oblivious as to the occurrences in London, where Mr. Watt's communication excited so much attention, had been intimately known to Blagden himself, had gained most honourable applause from many learned persons, and stood recorded in the books of the Royal Society as the first announcement of the discovery of the compound nature of water. When Mr. Watt's conclusions were first made known, and that to all the active members of the Royal Society, they laughed at them, says De Luc, as at the explanation of the golden tooth;[*] so great was their

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[*] The history of this egregious imposition is given at length by Daniel Sennertus, a physician of Wittemberg, to whom it was communicated by D. Michael Doringius, who again had received it from Daniel Bucretius of Vratislau. It is copied from Sennertus by the learned Dr. Antony van Dale, in his second Dissertation, 'de Oraculis Ethni- ' corum,' (pp. 474, 475, edit. Amst. 1683), and is thence adopted by Fontenelle; who, in somewhat abridging the particulars of the story, has not failed to adorn it with the graces of his wit. We quote it in his words:—" En 1593, le bruit courut que les " dents estant tombées à un enfant de " Silésie, âgé de sept ans, il luy en " estoit venu une d'or, à la place " d'une de ses grosses dents. Horstius, Professeur en Médecine dans " l'Université de Helmstad, écrivit en " 1595 l'Histoire de cette dent, et " prétendit qu'elle estoit en partie " naturelle, en partie miraculeuse, et " qu'elle avoit esté envoyée de Dieu " à cet Enfant pour consoler les " Chrétiens affligez par les Turcs. " Figurez-vous quelle consolation, et " quel rapport de cette dent aux " Chrestiens, ny aux Turcs! En la " mesme année, afin que cette dent " d'or ne manquast pas d'Historiens, " Rullandus en écrit encore l'Histoire. Deux ans après, Ingolsteterus, autre Sçavant, écrit contre le " sentiment que Rullandus avoit de " la dent d'or, et Rullandus fait " aussitost une belle et docte Réplique. Un autre grand Homme, " nommé Libavïus, ramasse tout ce " qui avoit esté dit de la dent, et y " ajoûte son sentiment particulier. " Il ne manquoit autre chose à tant " de beaux Ouvrages, sinon qu'il fust " vray que la dent estoit d'or. Quand " un Orfevre l'eut examinée, il se " trouva que c'estoit une feüille d'or " appliquée à la dent avec beaucoup " d'adresse; mais on commença par " faire des Liures, et puis on consulta " l'Orfevre." "In 1593, the rumour " spread, that the teeth of a child, " seven years old, in Silesia, having " fallen out, a golden one had come " in the place of one of the large " teeth. Horstius, Professor of Medicine in the University of Helmstad, wrote, in 1595, the History of " this tooth; and pretended that it " was partly natural, partly miraculous, and that it had been sent from " God to this child, to console the " Christians oppressed by the Turks. " Fancy what consolation, or what " concern this tooth could be to the " Christians or to the Turks! In the " same year, in order that this golden " tooth might not want historians, " Rullandus wrote a second History " of it. Two years after, Ingolsteterus, another philosopher, wrote " against the theory which Rullandus " had about the golden tooth, and " Rullandus forthwith makes a fine " and learned Reply. Another great " man, named Libavius, collects all " that had been said of the tooth, " and adds his own theory. Nothing " else was wanting to all those fine " books, except that it should be true " that the tooth was of gold. On a " goldsmith examining it, he found, " that it was a leaf of gold applied " to the tooth with much address; " but they began by making books, " and *then* they consulted the goldsmith." Fontenelle, 'Histoire des ' Oracles,' p. 22, édit. d'Amst. 1719. The Treatise of Horstius referred to, is appended to that edition of his book, 'de Natura, Differentiis, et ' Causis eorum qui Dormientes Ambulant,' which was printed at Leipzig in 1595. A work which seems to have escaped the notice of both Van Dale and Fontenelle, is the ' Tractatus de Dente Aureo,' of Dr. Duncan Liddel, a native of Scotland, Professor of Mathematics and of Medicine in the same University with Horstius. It was printed at Hamburg in 1628.

Sennertus ends his narrative with this apposite moral:—" Quæ historia wonder, so strong their disbelief. But Mr. Cavendish's friends are not said by Blagden to have testified any surprise, or any incredulity; yet "the conclusions," as Lord Brougham has truly said, "are identical," with the single difference as to heat, in which respect the discoveries of modern chemists have shown that Mr. Watt's had greatly the advantage. But the novelty was gone, and the disbelieving wonder had ceased. When Blagden says only, that both communications were made in "the Spring," and "about the same time," he claims for his patron no priority; he is content to insinuate for him only a very questionable sort of independence in the discovery;—nay more,—for that is the result to which the evidence brings it,—he can for Mr. Cavendish, as against Mr. Watt, neither claim priority, nor establish independence.

In Mr. Cavendish's paper as first written, and as read on the 15th January, 1784, he made no mention whatever of Mr. Watt's theory. Yet it appears from the letter to Crell, that Blagden was not uninformed at a much earlier period, (viz. the Spring of 1783), of Mr. Watt having formed "an opinion" similar to that of Cavendish; he confesses that "the news "was brought to London" in the same Spring; that he knew it, at latest, before June; and he authorised Kirwan to tell Mr. Watt that he had even heard his paper read; the 'Philo-'sophical Transactions' prove that it was known, from Mr. Watt's own letter, to many members of the Royal Society; De Luc says it was known to all the active members, and to Dr. Blagden especially, who had full acquaintance with Mr. Cavendish's paper, both before it was read, and at its reading; and, lastly, it is highly probable that Blagden first heard of Mr. Watt's theory from Cavendish himself,—at least Mr. Watt evidently so interpreted Kirwan's letter. Blagden certainly nowhere asserts that Cavendish was not aware of it. Neither does Cavendish himself. Why, then, did he suppress, so far as depended on him, all notice of the theory which had thus been formed elsewhere, and of which he well

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"omnes naturae scrutatores meritò "monere debet, ne causas rei, et ΤΟ "ΔΙΟΤΙ prius quærant, quàm ΤΟ "ΟΤΙ sit manifestum, et de re ipsâ "planè constet."

knew the vast importance,—which was then many no old,—and to which his own was so wonderfully conforme to be justly termed, "*its proof and exposition, word for w* Why did he so readily grasp at the undivided merit of discovery, but never once name the discoverer who had l treading, as even he must have admitted, with no une steps, and, as it was very soon proved, even in advan himself, in the same path?

But, in the next place, when,—after Mr. Watt's pape been read to the Royal Society,—Blagden added a pa which was adopted and printed as his own by Cavendish therein mentioned both the name and the theory of Mr. why did neither of the two coadjutors say a single w enlighten the scientific world on the dates at which th theories respectively were formed? Or, was this unac able and highly suspicious desideratum supplied, whe later period, Blagden undertook to give his "best acc of the matter? On the contrary, although he declar voisier to have known of the conclusions of both W Cavendish, and, therefore, to have been posterior to t is still satisfied with trying loosely to couple those gether, as having arrived at the discovery somewhere "the same time." "Those conclusions," says I "opened the way to M. Lavoisier's present theory;" thus informs us who was, of three, the last discoverer does he not, in "the best account" of "the little venture to state the knowledge, which we well know have possessed, as to which of the other two was *the fi verer?* That was the only point which he professed t that is the only one which he leaves altogether un His "best account" is indeed a miserably bad one, himself and his friend; and of his phrase "*about* "*time*," it has been happily observed,* in the case of philosopher, that it was used "with a convenient "ambiguity, just sufficient for self-defence, shoul "charged with unfair appropriation."

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* By Lord Brougham, of Lavoisier, 'Men of Letters and Scien
in the Life of Dr. Black.—'Lives of p. 329.

Such is the whole state of the case for Cavendish; utterly deficient in any real claim to priority, even on the statement of his own friends,—let us rather say, of the only friend who has attempted to give testimony, solitary, partial, and obscure, in his favour.

There is one other point, on which, however, we touch unwillingly and briefly, because it is of a delicate nature, and we have no desire, nor, indeed, occasion, to draw from it any conclusion. For, as has been fully shown, Dr. Blagden's statements, even if perfectly correct, cannot be said to contradict Mr. Watt's priority. But it certainly ought not to be kept altogether out of sight, in estimating the value of any testimony given by Dr. Blagden on behalf of Mr. Cavendish, that he received from that distinguished chemist, both a considerable annuity for a great part of his life, and afterwards a legacy of fifteen thousand pounds.* Lord Brougham says that Blagden's legacy was generally understood to have fallen far short of his ample expectations.†

With regard to the annuity, the following appear to be the facts, as far as they can now be ascertained.‡ Early in 1783, Blagden became Cavendish's assistant; an annuity of 500*l.* being settled on him as his recompense for undertaking that office. In 1789, Cavendish and his assistant are said to have parted; *causa latet.* But the expression, that the annuity "was settled" on Blagden, leads us to suppose, in the absence of any information to the contrary, that it continued to be paid to him till the time of his death, which took place in 1820. Thus a sum of 18,500*l.* on account of the annuity, making, together with the legacy of 15,000*l.*, a round sum of 33,500*l.*, was received by Blagden from Cavendish for six years' service as his assistant. The money so got, increased and multiplied,—it is said, by speculations in the French funds;—and he, who began life as a poor army-surgeon, died a wealthy man, the probate of his will being sworn under 50,000*l.*

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* Mr. Cavendish's latter will we have seen. It was made 18th February, 1804, and commences with the bequest to Sir C. Blagden. It was proved 5th March, 1810.

† 'Lives of Men of Letters and 'Science,' vol. i. p. 446.

‡ See Wilson's 'Life of Cavendish.'

We are far from wishing to press the idea, that there was any deliberate intention on the part of Cavendish to exercise an undue influence over Blagden, by making him so large a recipient of his bounty in return for services rendered for so brief a time; or any design on the part of Blagden to earn his wages by the commission of iniquity; especially as the persons concerned in the matter no longer survive to defend themselves, and explain those parts of their conduct which may appear singular or doubtful. But in estimating the value, as evidence, of Blagden's testimony on behalf of Cavendish, we must unquestionably take into account the relative position of the parties, and the unavoidable bias by which such testimony must have been affected. Without doing or intending wrong to any one, or to any one's memory, we may venture to assert with perfect confidence, that when under these circumstances Blagden gives an account which he professes to be "the " best," of " the little dispute about the first discoverer of the " artificial generation of water," and therein asserts the priority of both Cavendish and Watt over Lavoisier, but scarcely ventures to hint, even in the most vague and general way, at any priority of Cavendish over Watt, it is very certain that, whatever might be the value of his evidence on the first of those points, it must be held to be conclusive against Cavendish on the second of them.

CHAPTER XXII.

ARGUMENTS OF THE ADVOCATES OF CAVENDISH — THEIR GROUNDLESSNESS — PRIORITY OF WATT MAINTAINED DURING HIS LIFETIME — OPINIONS OF PHILOSOPHERS SINCE HIS DEATH — DR. HENRY — SIR HUMPHRY DAVY — LORD BROUGHAM — ARAGO — DUMAS — BERZELIUS — SIR DAVID BREWSTER — LORD JEFFREY — LIEBIG — MR. WATT'S SCRUPULOUS SENSE OF JUSTICE — HIS ACQUAINTANCE WITH CAVENDISH — FESTIVITIES OF THE ROYAL SOCIETY.

BESIDES employing the argument arising from the reputation of Mr. Cavendish, which does not really affect the question of priority in the discovery, if established by other evidence, the advocates of Cavendish have made three principal assertions with the view of impugning M. Arago's accuracy. They have said, first, that Priestley "constantly maintained" that he had never found the weight of the water, produced in his experiment, equal to that of the gases exploded; secondly, that an undue licence had been used, in substituting the term *hydrogen* for *phlogiston*, as used by Mr. Watt; and thirdly, that the conclusions of Cavendish, which were first stated to the Royal Society in his paper read on the 15th of January, 1784, must be supposed to have been included, or involved, in his experiments made in 1781.

The first of these assertions might well be termed by M. Arago "inconceivable," when it is remembered that in Priestley's own paper he says,—"In order to judge more accurately "of the quantity of water so deposited, and to compare it "with the weight of the air decomposed, I carefully weighed "a piece of filtering paper, and then having wiped with it "all the inside of the glass vessel in which the air had been "decomposed, weighed it again; and *I always found, as near* "*as I could judge, the weight of the decomposed air in the* "*moisture* acquired by the paper."* In the very first pages of Mr. Watt's paper "on the Constituent Parts of Water," in describing Dr. Priestley's experiment, it is said,—"The "moisture adhering to the glass after these deflagrations, "being wiped off, or sucked up by a small piece of sponge "paper, first carefully weighed, was found to be *exactly, or* "*very nearly, equal in weight to the airs employed.*" And,— "These two kinds of air unite with violence, they become "red-hot, and, upon cooling, totally disappear. When the "vessel is cooled, *a quantity of water is found in it equal to* "*the weight of the air employed.*"* So in Mr. Watt's Correspondence, "he finds on the side of the vessel *a quantity of* "*water equal in weight to the air employed.*" † And again, "No residuum, except a small quantity of *water equal to their* "*weight.*" ‡ So also, "you will find *the water, (equal in weight* "*to the air*), adhering to the sides of the vessel." § The circumstance of the equality of weight was indeed one of the facts on which Mr. Watt repeatedly states that he founded his deductions; and, as will presently be seen, it is of great importance in more points of view than one.

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* 'Phil. Trans.,' 1783, p. 427.

The substitution of the term *hydrogen* for *phlogiston*, had been so amply explained by M. Arago, in the note on that subject which accompanied Lord Brougham's Historical Note,‖ that it might have been supposed no fair objection could have been raised to it by any one; even by the most injudicious and ill-informed partisan of Mr. Cavendish. M. Arago was also at the pains to produce a letter from Dr. Priestley to M. Lavoisier, dated 10th July, 1782, in which he says he has made "some experiments with inflammable air, that seem to "prove *that it is the same thing that has been called phlogiston.*" Dr. Priestley, in relating, in his paper of 1785, the theory which Mr. Watt had formed, says that he "concluded, &c., "that water consists of dephlogisticated *and inflammable air.*" But further, the professed difficulty might have been removed, if those who made it had chosen to profit by Mr. Watt's own note, (which, if they did not read, they at least ought to have read, and might have been supposed to have considered, because it is given both in the 'Philosophical Transactions' and in Lord Brougham's Historical Note), viz.: "Previous to "Dr. Priestley's making these experiments, Mr. Kirwan had "proved, by very ingenious deductions from other facts, that "*inflammable air was, in all probability, the real phlogiston in* "*an aërial form. These arguments were perfectly convincing* "*to me.*"*

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* 'Phil. Trans.,' 1784, pp. 332, 333.

† Mr. Watt to Mr. Gilbert Hamilton, 26 March, 1783.

‡ The same to the same, 22 April, 1783:

§ Mr. Watt to Mr. Fry, 28 April, 1783.

‖ 'Eloge of Watt,' p. 167.

So in Mr. Watt's paper we find these expressions:—"It "was reasonable to conclude, that *inflammable air must be the* "*pure phlogiston, or the matter which reduced the calces to* "*metals;*"——"*the inflammable air being supposed to be wholly* "*phlogiston;*"——"*inflammable air or phlogiston;*"——"it is "worthy of inquiry whether the greater part of the heat let "loose was not contained in *the phlogiston or inflammable air,*"† &c. &c. So, also, in writing to Dr. Black on the 21st of April, 1783,—the very day on which his letter to Dr. Priestley was first written, although the second edition, read a year afterwards at the Royal Society, was written on the 26th of the same month,—he says, "therefore *inflammable air is the* "*thing called phlogiston.*" So to Mr. Hamilton, on the 22nd of April, the first of the three deductions he states is, "*pure* "*inflammable air is phlogiston itself.*" Above all, in the same letter to Dr. Black, as if to exclude all possibility of any cavil being raised, on the ground of the language in which his theory is expressed, he further states his conclusion to be, "that water is composed of dephlogisticated *and inflam-* "*mable air.*"

Neither is the objection, thus groundlessly stated, an original one, nor has it now been for the first time effectually answered. For, nearly half a century ago, a very able pen thus wrote: "We have said that the theory of Mr. Watt is "now demonstrated to be true. To this assertion, an objec- "tion may be raised from the language in which he states "his theory; for he explains it by using the word 'phlo-

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* 'Phil. Trans.,' 1784, p. 331.

† Ibid., pp. 349, 350, 352.

" 'giston,' a word which is now exploded from philosophy as " the name of an imaginary substance. *But it is sufficient to " reply, that Mr. Watt uses the word phlogiston as synonymous " with inflammable air.*" * And that hydrogen, and not any other sort of inflammable air, (such as the gas from charcoal, on which also Priestley experimented), was intended by Mr. Watt, is evident from the circumstance of the equality of the weight of the water, on which, as reported by Priestley, he so much dwells; but which could not have been so exactly attained except by that particular gas being employed: as well as by Mr. Watt's expression of the inflammable air being " the matter which reduced the calces to metals,"—a very exact description of hydrogen, and of no other gas.

It is evident that the term *hydrogen*, derived from the Greek word for water, and designating one of its constituents, could not have been invented till after the composition of that fluid had been ascertained. Lavoisier himself, the inventor of the term, did not use it till a later period; and he expressly says, in the beginning of his paper, " The inflammable air " which I understand when I mention it in this Memoir, is " that which is obtained, either from the decomposition of " water by iron alone, or from iron and zinc dissolved in " vitriolic and marine acids; and, as it appears proved that " in all cases that air comes originally from water, I shall " call it, when it presents itself in the aëriform state, *aqueous " inflammable air;* and when it is engaged in any combina- " tion, *aqueous inflammable principle.*" That passage is one of those additions to the paper, which are said not to have been made till after November, 1783; for it contains an allusion to the experiments made with M. Meusnier, which had not been performed at that date, but were described in the Memoir read at Easter, 1784.

But in what respect was Cavendish superior to Mr. Watt on this point? Even in 1784 he used neither the term hydrogen at all, nor uniformly the term inflammable air; for his conclusion is in that year thus stated:—" There seems

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* Article 'WATER,' Encyc. Brit., 1797.

" the utmost reason to think that dephlogisticated air is only " water deprived of its *phlogiston*, and that inflammable air is " either phlogisticated water or else pure phlogiston; *but in* " *all probability the former*,"—a conclusion infinitely more dim and distant from the truth than those which we have just cited from Mr. Watt's paper and letters. Such also is the language in which the rest of Mr. Cavendish's paper, on this subject, is couched; and even with all the additional lights supplied by Watt and Lavoisier to guide him, it is undeniable that his conclusions are at least as much embarrassed and disguised as those of either of the others: while M. Arago, that equal justice might be done to all parties, used exactly the same substitution in speaking of Cavendish's labours; thus making them, as well as those of Mr. Watt, more intelligible to those accustomed only to the modern nomenclature.

Lastly, it has been asserted, that Cavendish's mere experiments, apart from the formation of any theory, " involved " the notion, and established the fact," of the composition of water. So in some sense did Priestley's;—so did Warltire's; nay, on the same principles, it might be hard to withhold the merit of priority from Macquer and Sigaud de Lafond, who, by the combustion of gases, produced water which appeared to them to be pure. It may be true that Macquer's data, so far as he has recorded them, were scarcely sufficient to have led him readily to form a just opinion on the subject. But Priestley and Warltire, in their experiments of 1781, came very much nearer the last experimental step afterwards arrived at by Cavendish: the loss of weight which Warltire detected after the combustion was almost imperceptible, and was at once to be accounted for by the least imperfection in his apparatus. Yet they both confidently attributed the formation of the dew to the mere deposition of suspended moisture.

So late as 1784, Meusnier and Lavoisier, in the commencement of their Memoir on the Decomposition of Water,* remark, that "there have nevertheless been doubts raised on that "entire reduction of two aëriform fluids into water; and, "notwithstanding the precautions taken by M. Lavoisier, to "ensure, as much as possible, precision in so delicate an "experiment; notwithstanding the conformity of the result "obtained nearly at the same time by M. Monge, in the "laboratory of the school of Mézières, with a very exact "apparatus and the most scrupulous attention, some persons "have believed, that the water which proceeds from that "operation may be attributed to humidity held in solution "by the airs, and deprived of support at the moment of their "combustion." Such was, then, the experience of MM. Meusnier and Lavoisier, who, it will not be denied, had the best means of ascertaining the impression really made on the scientific world by those experiments, which, to their own minds, had brought conviction of the truth of the theory of the composition of water. And in that Memoir, read as late as the 21st of April, 1784, when the conclusions of Watt, and the able reasoning of Lavoisier in his first paper, and the views of Cavendish, and the confirmatory observations of La Place, and Meusnier, and Monge, had all become well known, those two distinguished philosophers thus found it needful to begin anew their argument, by that positive and particular statement of the opposition which was made to the theory, or at least of the difficulties which, with some, stood in the way of its reception.

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* 'Mémoires de l'Académie' for 1781, published in 1784.

In the same year, Mr. Kirwan appears to have thought that he ventured far in admitting himself to be "nearly convinced," that, when the two gases are fired, "water is "really produced."* The example of caution, which had been set by so many sage experimentalists, was further illustrated in the case of Dr. Black, who, in his correspondence with Mr. Watt, only remarks of the steps immediately preceding his discovery, that they appeared to him "very surprising;" and, in 1790, thus wrote to Lavoisier:—"I long "experienced a great aversion to the new system, which

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* 'Phil. Trans.' for 1784, p. 167.

" represented as erroneous that which I had regarded as a " sound doctrine; nevertheless, that aversion, which was " caused by the power of habit alone, has gradually diminished, yielding to the clearness of your demonstrations, " and the solidity of your plan." *

Nay, the most conspicuous instance of the same truth, (at least in France, for it would be hard to point out a more signal one than Priestley), is to be found in the case of M. Monge himself. He, as has been shown,† was perfectly aware of the *result* of the combustion of the two gases; having performed the experiment on a greater scale, and obtained its product in a larger quantity, than was done by any other at so early a date; and yet he appears, at a period as late as 1786, when his paper was printed, to have entertained very uncertain notions as to the nature of the change which was operated, and very great doubts as to the theory, which would now be so idly represented to have been obvious to any one, who performed the experiments on which *it might have been founded.* After enumerating the various deductions which he thought possible, " either consequence," says M. Monge, " is equally extraordinary; and we could not decide between " them without experiments of another sort." And he concludes, " we have, then, need of much further light on this " subject; but we are entitled to expect it, both from time, " and from the concourse of the labours of physical enquirers." The hesitation in yielding his assent to the new doctrine, which Monge thus philosophically, but perhaps even too cautiously expresses, is as great, as the incredulity of Priestley was persevering. It is very interesting to find Monge in

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* 'Annales de Chimie,' viii. p. 227. It is said by Mr. Yeats, in his 'Observations on the Claims of the Moderns ' to some Discoveries in Chemistry and ' Physiology' (1798, p. 247), that when Lavoisier was informed, by this letter from Dr. Black, of his conversion to the anti-phlogistic doctrine, so great was his joy in having acquired such able support, that he published it in all the newspapers in Paris. It is an affecting incident, which we record on the same authority, that when Dr. Black, in an Introductory Lecture on Chemistry, came to the subject of the discoveries of Lavoisier, soon after that illustrious enquirer had become a victim to the fury of democratic tyranny, — the lecturer stopped, unable to proceed:—the generous feelings of a humane heart, recurring to the cruel circumstances of his death, prevented utterance.

† See above, p. 324.

1789 thus writing to Mr. Watt;—"The decomposition of "water by the electric spark, of which you have no doubt "heard by the 'Journal de Physique,' here stops the mouth "of the few unbelievers whom we still had; and it is no "longer doubtful, that that liquid is composed of oxygen and "hydrogen:"[*] and then immediately expressing the profound veneration he entertained for the talents and virtues of his friend, whom he evidently looked upon as the true author of the theory which had at last been so completely established to the general satisfaction.

In 1789, also, six years after the discovery had been made, Berthollet found occasion to write no fewer than fifty pages, (printed in the '*Annales de Chimie*' for that year), in confutation of some of the arguments then maintained against it; chiefly of those of Mr. Keir,[†] whose acuteness and ability were unquestioned, and to the extent of whose learning, Berthollet does all justice. Yet Mr. Keir's opposition was both zealous and obstinate. Even Berthollet, the author of the paper, a chemist equally judicious and original, and who is mentioned by Fourcroy as the first who solemnly renounced phlogiston, and adopted the doctrine of Lavoisier "with "ardour and loyalty," professes himself, at that time, only a recent proselyte to the doctrine which he had so adopted; with great candour admitting, that he had resisted it "longer "than perhaps befitted a philosophy, which should rise above "those secret motives which keep us bound down to our own "opinions."[‡]

Fourcroy speaks of "that brilliant discovery, which had so "many prejudices, so many obstacles, so many ancient errors, "to overcome."[§] And, although he admits that within a few years it became the creed of a great part of the members of the Academy, he adds that they were obliged continually to defend it against the most desperate attacks. He himself soon followed the example of Berthollet, and of his friend

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[*] 'Mechanical Inventions of Watt,' vol. ii. p. 237.

[†] In the article 'NITRIC ACID' in his Dictionary of Chemistry.

[‡] 'Ann. de Chimie,' iii. p. 114.

[§] 'Système des Connoissances Chimiques,' tome i. p. 37.

Guyton-Morveau, whose conversion took place in the close of the year 1786.*

The experience of every observant student of chemistry, who beholds for the first time the wonderful experiment in which water is formed, will serve to convince him that at that period such hesitation, or even denial, was not so unnatural as to have been at all surprising, or very discreditable to the acumen of those who entertained it. Even if any chemist of the present day, looking at Mr. Cavendish's experiments with the great additional light which the improved state of our knowledge now affords, should find it difficult to suppose, that the mere facts observed, and results obtained, should not at once have received the interpretation which was afterwards put upon them,—let him reflect whether great weight is not also due to these considerations; viz.—That if Mr. Cavendish had formed his theory in 1781, he most probably would have mentioned it, or alluded to it, before 1784, or even 1783; or, at least, that when he did make it known, he would have named the earliest date at which he could say that he had formed it. If the probability of either, or both, of these things be admitted, it must also be admitted, as a consequence from the facts as ascertained, that he probably did not form his theory,—as he has not even pretended to have stated it,—previous to "the Spring of 1783;" or, in other words, previous to his knowledge of Mr. Watt's paper.

Besides, if the theory could not be separated from the experiments, but was necessarily involved in them, so as to have been apparent to any chemical philosopher, or even any common observer, who was informed of them; and if it be true, as stated by Blagden in Mr. Cavendish's paper, that "all the experiments were made in 1781, and mentioned to "Dr. Priestley," how came *Dr. Priestley* not to see in them the conclusion represented to be so unavoidable? Or how came Lavoisier and La Place not to believe the communication of Blagden at Paris in June, 1783? Yet we know, that even in 1783, they all viewed Mr. Watt's theory, which was so nearly identical with that afterwards promulgated by Cavendish, as entirely novel; nay, as, at first sight, quite incredible.

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* 'Système des Connoissances Chimiques,' tome i., p. 40.

It is thus impossible to say, that the experiments necessarily imply the conclusions; or to consider the right explanation of that most remarkable phenomenon as having been included in the mere observation of the preliminary fact. To argue the reverse, is to betray an ignorance of the writings of the many eminent philosophers who doubted, and even denied the true theory, after it had received what modern chemists may consider irresistible confirmation. Cavendish appears, from his own diary of experiments, as well as from all the statements of himself and his friend Blagden, never to have expressed even a suspicion of the theory of the composition of water, till after the date of Mr. Watt's paper April, 1783; when "the notion," and "the fact," were alike, for the first time, made generally known. It is q incredible that he could have made so surprising a disco and satisfied himself of its truth, and then thrown it for years, without even stating, at any time, in any w to any individual, that he had done so; especially w "little dispute," as Blagden calls it, arose as to the p and assertions were distinctly made on the other side, uncontradicted as they have been, certainly place Mr. dish second in order of time.

After all that has now been said, it can hardly be necessary that we should gravely answer the ridiculo tion, that Mr. Watt did not in his lifetime put forwa tinct claim to the honour which was justly his due. may be proper, as it is easy, to refute the further n ment, that Cavendish "was universally regarded, "continued to be regarded, as the sole author of th "discovery;" and that "it was only in later tin "attempts have been made to upset this unanimous "in his favour, when there are no living witnesses "impression which prevailed among his contemporari

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* 'Quarterly Review' for December, 1845, p. 137.

Mr. Watt's note in the 'Philosophical Transactions,' which most effectually declares his priority, was never contradicted nor called in question by Cavendish, or any of his friends; to all of whom,—and especially, as we have seen, to Dr. Blagden,—it was well known, being printed in the same volume with both of the papers.* Having, by that note, done all that became so high-minded a man and so true a philosopher, he could well afford to despise any portion of fame that might have been gained by more elaborate or less worthy means. "When the theory of the composition of water was spoken "of in the presence of my father," said Mr. James Watt, junior, "he calmly but uniformly sustained his claim to its "discovery; and once, on my hinting that it was passed over "by some writers, and not correctly given by others, he "observed, that having done all that he and his friends con-"sidered requisite to place it upon record, by the note affixed "to his paper of 26th November, 1783, in the 'Philosophical "'Transactions,' the accuracy of which had never been ques-"tioned, *he should leave posterity to decide*." † Well might he have used the words, as he always exemplified the sentiment, by which one of the most eminent of his admirers, in another country, has added grace and dignity to his own memorable labours. "Though the opinions," says M. Dumas, "to which "my researches have conducted me, might have given room "for more than one discussion, I shall be pardoned for having "deemed myself above those vain polemics. The moments "which I rescue from them are devoted to ascending by "experiment to the sources themselves of truth; and I trust "that they are thus more usefully employed for the interests "of that science, to which I have consecrated my life." ‡

Mr. Watt's constant occupation in pursuits which he was obliged to prefer even to his chemical studies, as still essential to the advantage both of himself and his cou together with his "contempt for the modicum of fame wh "would result from such a discovery,"—nay, even the i lence of which he frequently speaks as constitutional, bu which the great works he accomplished certainly exhibi trace;—above all, his extreme modesty, and absolute dete tion not only of appearing in any way to celebrate his praises, but even of being compelled to listen to them; combined to prevent his taking other steps for ensuring to himself, than were absolutely essential for placing hi ority upon record. In his own person he formed onl good an illustration of the words of one of his letters t Black,*—"all this you bring on yourself by not publi "your discoveries." And the foresight of the same obs and sagacious friend led him to write to Mr. Watt in emphatic words;—"Were you to be the first publi "your discoveries, *you would do it in such a cold and* "*manner, that blockheads would conclude there was no* "*it, and rogues would afterwards, by making trifling va* "*vamp off the greater part of it as their own, and a* "*whole merit to themselves.*"† A remarkable pred most singularly verified!

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* It deserves to be mentioned, that in the Abridgment of the Papers in the 'Philosophical Transactions,' prepared by Hutton, Shaw, and Pearson, Mr. Watt's important note is, very improperly, omitted. This may account for Cavendish having received the credit of the priority, with some of those who on subjects of scientific interest do not consult original authorities.

† Letter to the author, 5 February, 1846, printed with the 'Correspondence on the Discovery of the 'Composition of Water.'

‡ Preface to 'Mémoires de Chimie,' Paris, 1843.

Further, we have shown that the doubly errone which were inserted in the Papers printed under immediate superintendence, as Secretary to the Roy in 1784, were calculated entirely to mislead the w Mr. Watt being first, and Cavendish last, in the or, at least, could not fail to produce much conf uncertainty, as to the relative priority of their theories. That this purpose was in great measur as regards some chemical authors, is proved by sistencies of various works which touch on the poi practice unquestionably prevailed with many write country, (some of whom did little more than copy others), of speaking loosely of "Mr. Cavendish's d just as in France the same thing was done in regard to Lavoisier, La Place, Monge, and Meusnier.

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* Sept. 25, 1783.

† Dr. Black to Mr. Watt, 13th

But to that rule there have also been many exceptions. Thus Nicholson, in his preface to the translation of Fourcroy, published in 1788, says, "Mr. Watt has therefore a claim to "the merit of a discoverer with regard to the composition of "water, and has the advantage of priority in the discovery of "its decomposition."[*] The same statement is repeated in his 'Chemical Dictionary,' in 1795;[†] although in both places Mr. Cavendish also is called a discoverer. In the excellent article on Water, in the third edition of the 'Encyclopædia 'Britannica,' published in 1797, it is distinctly said,—"with "respect to Mr. Watt, we think it appears that he was the "first person who formed the true theory." In the translation of the fifth edition of Fourcroy, published, with numerous valuable notes, by the late Dr. John Thomson of Edinburgh, the very learned translator has supplied the undue omission of his author;—"It is but justice," he says, "to add, that "the same inference had been made by Mr. Watt, and com"municated by him in a letter to Dr. Priestley, dated April "26, 1783. See 'Phil. Trans.,' vol. lxxiv. p. 330."[‡] Lord Brougham, writing in the 'Edinburgh Review' in 1803, ably stated for the first time the opinion to which his early studies had led him, and which the additional inquiries of half a century have so materially confirmed, viz. that "some "ingenious men, particularly Mr. Watt, reasoning from all "these facts, concluded that this fluid is a compound of the "two airs, deprived, by their union, of a considerable portion "of their latent heat; the quantity, viz. which is necessary for "maintaining the elastic state."[§] In Dr. Thomas Thomson's 'Chemistry,' 1804, 1807,[‖] and Murray's 'Chemistry,' 1806, 1819,[¶] while the independence of Mr. Cavendish is maintained, the priority is assigned to Mr. Watt. Dr. Dalton, in his 'New System of Chemical Philosophy,' in 1810,[**] says, that "the composition and decomposition of water were ascer-"tained; the former by Watt and Cavendish, and the latter "by Lavoisier and Meusnier." In his 'History of the Royal 'Society' also, published in 1812, Dr. Thomas Thomson says, after having mentioned Cavendish's paper, "Mr. Watt had "previously drawn the same conclusion from the experiments "of Dr. Priestley and Mr. Warltire." *

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[*] Vol. i. p. 14.

[†] P. 1020.

[‡] Thomson's Fourcroy, vol. i. p. 240, 1798.

[§] 'Edin. Review,' vol. iii. p. 11.

[‖] Vol. i. p. 577; vol. ii. p. 109.

[¶] Vol. ii. p. 158; vol. ii. p. 111.

[**] Part II. p. 210.

All of these statements excepting the last, were made during the life of Cavendish, who died in 1810; and the whole of them were made in the lifetime of Watt, who died, as is well known, in 1819; and also in that of Blagden, who died in the following year.

After the death of Mr. Watt, his correspondence and the relative papers on this subject were submitted by his son to various learned persons, most competent to form a just opinion of their importance, and of the facts which they establish; to Sir Humphry Davy, Mr. Corrie, Sir David Brewster, and, among the rest, to Dr. William Henry of Manchester, who has been termed by Lord Jeffrey, "probably "the very highest authority that could have been referred to "on such a subject." In regard to Dr. Henry and his opinion, the most forward advocate of Cavendish, the Rev. William Vernon Harcourt, Canon of York, in a postscript added to an address which he read to the British Association, thought proper to make the following assertion:—"Though "I have not had the advantage of studying the unpublished "MSS. of Watt, I know that they were submitted to the in-"spection of the late Dr. Henry, with whose reputation as "a pneumatic chemist M. Dumas is well acquainted; and "whose knowledge, acuteness, and candour, were such as "eminently qualified him to judge in such a question; and "I learned from Dr. Henry, that these MSS. produced no "change in his opinion as to Cavendish's title to be con-"sidered the first discoverer of the composition of water." † Now, the late Dr. Henry was the only witness summoned by Mr. Harcourt as acquainted with the MSS. of Watt; and,

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* P. 471.

† Mr. Harcourt's Postscript to his Address, p. 26.

from the silence of the grave, Mr. Harcourt seemed not to have feared to receive contradiction.

Happily, Mr. James Watt, junior, had preserved, and we have seen, Dr. Henry's original letter of 8th June, 1820; in which, under his own hand, his opinion at that time is thus stated:—

"I have made use of the very first moments of leisure that have occurred to me since you were here, to look attentively over the papers of Mr. Cavendish and your father, and the other documents which you pointed out to my notice.

"*There is no room for doubt as to your father's priority.*

"*It is established beyond all dispute, by a comparison of dates, that your father was the first to interpret rightly the important experiments showing the synthesis of water.*

"*I should say that your father was the first who had the sagacity to draw the right conclusion from the experiment of Dr. Priestley, and to take that view of the constitution of water, which, to this time, continues to be received by philosophers as the true one.*"

The entire letter, written *before* Dr. Henry had read the correspondence afterwards published, is given below.* It seems

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* *Letter from the late Dr. Henry of Manchester to James Watt, Esq., Aston Hall.*

"MANCHESTER, 8th June, 1820.

"MY DEAR SIR,—I have made use of the very first moments of leisure that have occurred to me since you were here, to look attentively over the papers of Mr. Cavendish and your father, and the other documents which you pointed out to my notice.

"It does not appear that Mr. Warltire has a claim to any share in the discovery of the composition of water. His sole object was to ascertain, by firing dephlogisticated and inflammable airs in a close vessel, accurately weighed before and after the experiment, whether heat be ponderable* or not. The results which he obtained indicated a small loss of weight, but these must have been rendered erroneous by some defect of his apparatus, which, being of copper, prevented him from observing the production of moisture, subsequently remarked by Dr. Priestley, when the process was repeated with the substitution of a vessel of glass. Dr. Priestley, also, first remarked the almost entire condensation of the two gases, and the correspondence of their weight with that of the water formed. 'This water,' your father observes, ('Phil. Trans.,' vol. lxxiv., p. 333), 'is, then, the only remaining product of the process, and 'water, light, and heat, are all the 'products, unless there be some 'other matter set free which escapes 'our senses;' and then immediately follows the conclusion, 'that water 'is composed of dephlogisticated air 'and phlogiston,' (a term then used as synonymous with hydrogen gas, which had just come to be con-by it, that Dr. Henry *absolutely excludes Mr. Cavendish as a discoverer.* For he rightly attributes to Priestley the making the experiment, with the important observations of the deposit of water, and of the equality of weight; and to Cavendish merely the praise of performing the one and repeating the other with precision. He assigns to Mr. Watt *the whole merit of the discovery of the theory.* As to the distinction which Dr. Henry seems to have been then inclined to make, between *the discovery of the composition*, and *the discovery of the theory of the composition*, of water, because Mr. Watt drew his conclusions from an experiment of Dr. Priestley's, we leave it to others to say how any share of the credit of the discovery can possibly attach to Dr. Priestley; who, though he made that experiment, and thus unconsciously furnished the facts on which Mr. Watt's reasoning was in great measure founded, *uniformly denied the whole doctrine of the composition of water, and was never persuaded to believe in it.* It is evident

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"sidered as pure phlogiston), 'deprived of part of their latent or elementary heat.' This just inference from the facts is distinctly ascribed to your father by Mr. Cavendish himself, (same vol., p. 140), and there is, therefore, no room for any doubt as to your father's priority. The subject was next prosecuted by Mr. Cavendish, with that admirable sagacity and precision for which he is so justly celebrated, and it was not till after his experiments that those alluded to by your father, (p. 333), as made at Paris on large quantities of the two airs, appear to have been performed.

"It is, therefore, established beyond all dispute, by a comparison of dates, that your father was the first to interpret rightly the important experiments showing the synthesis of water. But as the experiment leading to this doctrine originated not with him but with Dr. Priestley, I am not sure whether it would not be too comprehensive a claim to assert for your father, 'the discovery of the composition of water,' to which extent, if I recollect rightly, your method of stating it goes; for this would imply that the facts were discovered by him, and not merely that he had reasoned correctly on the facts of another person. I should, therefore, rather say that your father was the first who had the sagacity to draw the right conclusion from the experiment of Dr. Priestley, and to take that view of the constitution of water, which, to this time, continues to be received by philosophers as the true one,—or something to that effect. In the case of your father, there is such a firm foundation, in discoveries most beneficial to mankind, for a great and imperishable fame, that it is perhaps better to claim less rather than more than his due,—a sentiment which has evidently influenced the general tone of the memoir which you were kind enough to show me, and of which I expressed to you very warm and very sincere approbation.

"I hope that I shall again have the pleasure of seeing you, and for a longer time, as you pass southwards; and in the meantime I remain,

"My dear Sir,
"Yours very faithfully,
(Signed) "William Henry."

that Mr. Cavendish also might well have performed the experiment, without drawing the conclusion.

Mr. Watt, on the other hand, as we have already shown, announced first in order of time, and with the utmost clearness, the real nature of the composition of water, and the proportion in which the two gases combine to form it. In the words of Lord Brougham's note on his 'Natural Theology,' published in 1835, " Dr. Priestley drew no conclusion of the " least value from his experiments. But Mr. Watt, after " thoroughly weighing them, by careful comparison with " other facts, arrived at the opinion that they proved the " composition of water. This may justly be said to have " been the discovery of that great truth in chemical science. " I have examined the evidence, and am convinced that he " was the first discoverer, in point of time; although," his Lordship then continued, " it is very possible that Mr. Cavendish may have arrived at the same truth from his own experiments, without any knowledge of Mr. Watt's *earlier* " process of reasoning."

The opinion which the late Dr. Henry expressed to Mr. Watt, junior, *after* having carefully read the Correspondence, is given in a note to his letter to the author, published in 1846, as follows:—" Dr. Henry afterwards, in the years 1835 " and 1836, called upon me, and inspected the original correspondence, which had the natural effect of strengthening " the opinion he had formed and expressed in 1820; and " upon the latter occasion he mentioned his intention of " writing a History of Chemistry, in which he said he should " do justice to my father's claims to the priority." But that nothing may be wanting to complete the information which on this point we are anxious to supply, we beg next to give some passages of a letter from Dr. William Charles Henry; whose learned accomplishments still worthily adorn that name, which the well-known merits of his father and grandfather have so long endeared to science.

" Mr. Vernon Harcourt, I observe, in the newspaper record " of his opening speech at Birmingham, has challenged the " accuracy of M. Arago's adjudication of your father's and

"Cavendish's claims to the discovery of the composition of "water. * * * *My father, I distinctly remember, came last "from a visit to you, after a full examination of the documentary evidence you submitted to him, impressed with a clear "conviction that Mr. Watt was the first to interpret justly the "experiment of the synthetic formation of water, and must be "regarded as the discoverer of the true theory of its composition.*" *

Such are the facts of Mr. Harcourt's attempt,—and failure,—to come to the rescue of Cavendish. They speak for themselves. And we think that our readers will agree with us that after the full publication of Dr. Henry's letter, and the strong corroborative assurance afforded by his son, some retractation, explanation, or apology, ought to have been offered by Mr. Harcourt of the statement which he so unfortunately made. None such, however, has yet been given; and we can only add, with Lord Jeffrey, that "We should be more "sorry for Mr. Harcourt, in making this annunciation, if he "had shown a less unbounded confidence in his own reasonings and powers of refutation; as it is, we can only hope "that he may at length profit by the rebukes he has drawn "down on himself; and that, if he should take the field "again, he will at least avoid the error of ushering in his "defeat by a song of triumph."

Sir Humphry Davy's opinion on the matter having been referred to, may, with propriety, here be noticed. In his 'Elements of Chemical Philosophy' † he slightly alludes, (as many others have done in the same loose way of speaking), to Mr. Cavendish's two discoveries of the composition of water and of nitric acid. But in one of his lectures, supposed to have been written about 1806, the more particular account he gives is, that in 1781, "Mr. Cavendish, in a process conceived with his usual sagacity, and executed with his usual "precision, showed that when common air and hydrogen "were exploded together, in the proportion of two and a half to one, the product was pure water, which exactly corresponded in weight to the gas consumed. And Mr. Watt, reasoning on this experiment, formed the conclusion that water consisted of pure and inflammable air, deprived of the greatest portion of their latent heat." Now, the experiments on which Mr. Watt reasoned were, as has been seen, not Cavendish's, but Priestley's. But the great and important distinction is clearly drawn, between Mr. Cavendish's mere observation of a fact, and the explanation of it by the theory which Mr. Watt formed. When, in 1824, Mr. Watt's correspondence on the subject was laid before Sir Humphry, he read the letters over, says Mr. Watt, junior, "with much interest, " and appeared exceedingly struck with their contents. He " expressed concern at the effect which their publication must " produce, (a concern not unnaturally proceeding from his " known attachment to Mr. Cavendish), and he did not then, " or at our subsequent meeting in 1826, endeavour to lessen " their force, or to call in question the deductions resulting " from their perusal. In the last conversation I had with him " here on the subject, he said he thought that my father's " theory, admitting the latent heat, would prove correct." *

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* Dr. William Charles Henry to Mr. James Watt, 4th Jan. 1840.

† Vol. iv. p. 30, of the edition of his collected works, published by his brother, Dr. John Davy.

In the Memoir of Mr. Watt which was published in 1824, in the sixth edition of the 'Encyclopædia Britannica,' his just claims to the priority of the theory of the composition of water, are concisely but comprehensively detailed. They were made more widely known by the eloquent 'Eloge of Watt' read by the late lamented M. Arago before the Institute of France, on the 8th of December, 1834, and published in the 'Mémoires 'de l'Académie des Sciences,' as well as in the 'Annuaire du 'Bureau des Longitudes' for 1839, accompanied by the able and interesting Historical Note by Lord Brougham,† and by some other notes added by the late Mr. James Watt, junior. In January, 1840, on the occasion of M. Arago presenting to the Academy of Sciences a Translation into English of the 'Eloge,' the statement which it contained of Mr. Watt's claims

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* Letter from Mr. James Watt, junior, to the author, printed with the 'Correspondence of Watt on his Discovery of the Composition of Water,' 1846, pp. ix., x.

† See Appendix.

received the emphatic corroboration of M. J. Dumas; who stated, that after having attentively examined the reasoning of his fellow-member, after having also scrupulously studied the correspondence preserved at Aston Hall,[*] he adopted "completely and in all its parts," the history which M. Arago had written of the discovery of the composition of water; and that his opinions upon that point were so decided, that he desired his declaration to be inserted in the Compte-Rendu of the meeting. "And a more authoritative deliverance," says Lord Jeffrey, "we suppose will not easily be found in any "such register."[†]

Than M. Dumas, a more competent judge of such a question could not possibly be imagined; for, while his own reputation as a scientific chemist is, probably, unsurpassed in Europe, and while he has shown, in common with M. Arago, complete impartiality, in deciding against the claims of his much distinguished and lamented countryman Lavoisier, he happens to be also especially conversant with every part of the subject itself. The details of a prolonged series of most laborious and skilful experiments, whereby he was enabled to correct the errors into which MM. Berzelius and Dulong had been led, and for the first time to establish with minute precision, the exact proportion in which oxygen and hydrogen combine to form water, are to be found in his valuable *Mémoires de Chimie*;[‡] and well deserve the attentive perusal of all those who can appreciate the merit of ingenuity, perseverance, and accuracy, in matters demanding the most difficult, protracted, and refined investigation. M. Dumas, when in England, in 1847, on a mission from his Government, again came forward to state that he had only been confirmed in the opinion which he had put on record some years previously, by the consideration of all that had since been published on *both* sides of the question. And he added, that in the correspondence and other manuscripts on the subject of the composition of water, which he had occasion to study attentively with a view to that full account of Lavoisier's life and works which he is now preparing,—and which, we may observe, the scientific world has long been eagerly expecting,—he had found "strong additional reasons for awarding the whole "glory of that great discovery to Watt." *

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[*] The original letters were submitted to his perusal by Mr. Watt, junior, as they had before been to M. Arago.

[†] 'Edinburgh Review' for January, 1848.

[‡] 'Mémoires de Chimie, par M. J. Dumas, Membre de l'Institut.' Paris, 1843, p. 395.

The learned and philosophical chemist of Sweden, Berzelius, in 1841, on a deliberate review of the works then published on this subject, has, without hesitation, assigned to Mr. Watt that merit and priority of date, which so many other learned men have with justice attributed to him: saying that it is clear that he arrived at his conclusions eight months earlier than Cavendish, who could scarcely have been ignorant of them when he wrote his paper; and only expressing a doubt as to whether he used the term phlogiston as synonymous with inflammable air, or hydrogen gas, and whether he did not amend his views on the publication of those of Lavoisier.† We have adduced incontestable proof, in no fewer than eight distinct passages from Mr. Watt's own writings, besides those cited from Priestley and others on the same point, of his having considered phlogiston and inflammable air to be identical; and all of those were written previous to his knowledge of Lavoisier having *even entered upon the subject.* Mr. Watt's note, given above at p. 359, further shows that he was "perfectly convinced" of inflammable air being "the real phlogiston in an aërial form," even previous to Dr. Priestley making his experiments.

As Berzelius further expressly says, that if we translate the quotation from Mr. Watt's paper into the language of the anti-phlogistic chemistry, (*i. e.* if we translate the word phlogiston into inflammable air, or hydrogen gas, and dephlogisticated air into oxygen gas), his conclusion is indisputable, we cannot but feel that any censure he bestows on M. Arago for making that translation, which the facts so fully warrant, is wholly undeserved. For, however various may have been the meanings attached to the word "*phlogiston*," by other chemists of the phlogistic school, we have shown that there can be no mistake as to what *Mr. Watt* meant by it, when he formed his famous conclusions; as he founded them in great measure on the circumstance, reported by Priestley, of the equality of weight between the gases fired, and the water produced: a result which could not so exactly have been obtained if any other inflammable air except hydrogen had been fired with the oxygen or dephlogisticated air.

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* 'Edinburgh Review' for January, 1848, vol. lxxxvii., p. 85.

† Berzelius, 'Jahres-Bericht über 'die Fortschritte der physischen Wissenschaften,' II. Heft. pp. 43-51. Tübingen, 1841.

Nor was the acceptance with which such views were received confined to those who had previously espoused the cause of Watt, or who had remained without preoccupation on the subject. As an instance of the change which was wrought by the force of truth on the convictions of others equally distinguished, we may mention a most eminent philosopher, who having, at a former period, on the imperfect information then open to him, been disposed to support the claims of Cavendish, on fully studying the fresh evidence which the correspondence of Mr. Watt first made public, unhesitatingly professed his entire conversion; and in one of those eloquent essays by which he has so often adorned the progress of scientific discovery, publicly announced, as the conclusion at which he had arrived, that the argument for Mr. Watt's priority "had now been placed on a sound and "impregnable basis." * That the name of Sir David Brewster should be known throughout the whole civilised world by the most brilliant discoveries in the most beautiful of sciences, can scarcely be deemed more honourable to him as a man, than the perfect candour which he thus displayed; and such unreserved testimony, spontaneously borne under such circumstances by such an authority, has evidently a most conclusive bearing on the question in regard to which it was delivered.

After the appearance of Sir David's fervent and powerful appeal, another eminent person, the late lamented Lord Jeffrey, consecrated the last, and we believe the longest, as it certainly is one of the very ablest of all his critical labours, to an admirable and truly judicial review of the whole controversy, then well-nigh its close.* His Lordship had, in 1819, penned the first and best eulogium that appeared on the occasion of the death of his venerated friend, "the inventor of "our present steam-engine;" and both of those works of love and respect to the memory of one whom he always delighted to honour, will long survive, as graceful memorials of their mutual fame, and of his unfailing affection. We need scarcely add that Lord Jeffrey was conducted, by his full examination of every argument used on either side of the case, to the conclusion that Mr. Watt was clearly the first original and complete discoverer of the compound nature of water; and that Cavendish never ventured to state his own theory until he had become acquainted with the discovery first committed to writing and publicly stated by Watt.

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* 'North British Review' for January, 1847, vol. vi. p. 497.

Lastly, Liebig, to whom the world is under obligations which it is almost impossible to overrate, for his application of chemical science to purposes of utility in many departments of practical life, in his 'Letters on Chemistry,' (adopting a similar view to that taken by Sir Humphry Davy, of the mere observation of a fact by Cavendish, but of its just interpretation by Watt), says, that "we value facts because "of their permanence and immutability, and because they "supply the soil for ideas; but *a fact acquires its true and "full value only through the idea which is developed by it.* "Many facts were not in the possession of Stahl, but the idea "is his property. Cavendish and Watt both discovered the "composition of water: *Cavendish established the facts, Watt the "idea.* Cavendish says, 'From inflammable and dephlogis- "'ticated air water is produced.' Watt says, 'Water consists or "'is composed of inflammable and dephlogisticated air.' Be- "tween these forms of expression there is a wide difference."

Had Mr. Watt's statement as to the date of his conclusions ever been called in question, or had he, like Mr. Cavendish, left no precise chronological statement at all;—had we been now forced to collect from other quarters, and for the first time, the facts on both sides of a disputed question, and to decide the cause according to the preponderance of such secondary evidence,—a chief consideration might have been, the peculiarities of character and disposition of the two principal parties. Even as matters now stand, with a priority of publication really incontestable, placed on record in the registers of the most learned body in the kingdom, and uncontradicted during the lives of any of the parties,—while it is by no means our wish to lessen the high reputation which Mr. Cavendish maintained, (however much that may have been exaggerated by the indiscriminate eulogy of others),—we may be forgiven if we dwell with pride on some characteristics of Mr. Watt, in which he was surpassed by no man, and could certainly have been equalled by few; which are not without a very important and obvious bearing on a question like the present.

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* 'Edinburgh Review' for January, 1848, vol. lxxxvii., pp. 67–137.

The Earl of Liverpool, when Prime Minister of England, after publicly declaring that on his personal knowledge he could aver, that a more amiable and excellent man in all the relations of life never existed, amply enlarged on the simplicity of his character, the absence in him of every thing like presumption and ostentation, and his unwillingness to obtrude himself not only upon the great and powerful, but even on those branches of the scientific world to which he more immediately belonged.* An orator and statesman still more distinguished, after mentioning that he had the happiness of knowing Mr. Watt for many years, in the intercourse of private life, said that those who were admitted to his society would readily allow, that any thing more pure, more candid, more simple, more scrupulously loving of justice, than the whole habits of his life and conversation proved him to be, was never known:—" There was one quality, which most " honourably distinguished him from too many inventors, and " was worthy of all imitation,—he was not only entirely free " from jealousy, but he exercised a careful and scrupulous " self-denial, and was anxious not to appear, even by acci-

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* Speeches at Freemasons' Hall, 18th June, 1824. Translation of Arago's 'Eloge,' p. 189.

"dent, as appropriating to himself that which he thought "belonged to others. * * The only jealousy I have known "him to betray, was with respect to others; in the nice adjustment he was fond of giving to the claims of inventors. "Justly prizing scientific discovery above all other possessions, he deemed the title to it so sacred, that you might "hear him arguing by the hour to settle disputed rights; "and if you ever perceived his temper ruffled, it was when "one man's invention was claimed by, or given to another; "or when a clumsy adulation pressed upon himself that which "he knew to be not his own." *

It is no derogation from his excellence, that he was at the same time not unconscious of "just pride, founded on great "talents and great services; that pride, which the most exalted and most worthy can justly indulge." † But his exemplary mind borrowed an additional grace from his habitual restraint of all such emotions; and we shall never forget the noble animation with which one of our most gifted and venerable Poets,‡ after having pointedly censured the unhappy passion for notoriety by which he conceived that some scientific men of the present day were too much actuated, fervently exclaimed,—"It was not so, that NEWTON made *his* discoveries, the grandest ever known; nor that WATT made *his*, "the most beneficial to mankind:—I look upon him, considering both the magnitude and the universality of his "genius, as perhaps the most extraordinary man that this "country ever produced; he never sought display, but was "content to work in that quietness and humility, both of "spirit and of outward circumstances, in which alone all that "is truly great and good was ever done."

Such is his enviable reputation as a man;—such his fame as a philosopher. And it is interesting in a high degree to remark, that for him, who had so fully subdued to the use of man the gigantic power of STEAM, it was also reserved to unfold its compound nature and elemental principles: as if on this subject there were to be *nothing which his researches did not touch,—nothing which they touched that they did not adorn.*

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* Lord Brougham's Speech, printed with the Translation of Arago's 'Eloge,' pp. 216-218.

† Sir R. Peel, in the House of Commons, 23rd January, 1846.

‡ Mr. Wordsworth, in September, 1840.

That to his thoughtful sagacity is due the glory of having first made that remarkable step in the progress of science, cannot admit of a reasonable doubt. Had Mr. Watt's discovery of the theory of the composition of water been, like very many of his inventions, directly available for the increase of his own wealth, and, as such, protected by a patent, most certainly no case has been made out, on the part of Mr. Cavendish, of such public use, or prior invention, as could have invalidated that patent. But, is honour to be meted out with a less liberal hand, or guarded with less jealous care, than those pecuniary rewards, which the true philosopher does not covet, and which few men would with equal ardour desire? Are learned Societies, or the individual followers and friends of Science, to be guided by less exact principles of justice, in their award of praise to *a first inventor*, than those impartial Tribunals where, in similar cases, but with other interests at stake, the great improver of the steam-engine found his rights vindicated, and his inventions sacredly protected, by the strong arm of the law?

> " Vilius argentum est auro, virtutibus aurum.
> " O cives, cives! quærenda pecunia primum est,
> " Virtus post nummos?"*

The result of the evidence on the whole case, as far as Mr. Watt's priority is concerned, we shall briefly express in these propositions, which certainly do not assume more than we have already proved; and of which every one who has been accustomed to the exactness of legal inquiries into matters of disputed discovery, will acknowledge the force.

First, that Mr. Watt formed the original idea in his own mind, and thus was A DISCOVERER of the true theory of the composition of water.

Secondly, that being a discoverer, he was also THE FIRST PUBLISHER of that true theory.

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* Hor. Epist. I. i. 52.

Thirdly, that being both a discoverer, and also the first publisher, he must therefore be held to be "THE TRUE AND "FIRST INVENTOR THEREOF."*

Thus, in the course of the controversy, all has been done that seemed essential for the fame of Mr. Watt, or that was requisite for a compliance with his own simple and memorable injunction, delivered nearly seventy years ago:†—"Preserve the dignity of a philosopher and historian; relate the "facts, and leave posterity to judge." And the history of that great discovery, after having received the most full elucidation and discussion, seems to have now left no just or reasonable doubt that Watt preceded Cavendish, as Cavendish preceded Lavoisier. Such is the general result into which the controversy on the subject may be said to have subsided; as, however averse the admirers of Cavendish naturally felt, at first, to resign any portion of what they had been in the habit of regarding as his own prescriptive domains, or uneasy at anything that seemed to question his independence and good faith in the transaction by which he acquired his title to their temporary enjoyment, it is only one or two of the most hardy or litigious of their number who now venture to maintain that the antiquity of his possession could, by any stretch of the evidence, be held to exclude the prior title of Watt.

For, on the present occasion, we can afford to exclude from the list of those judges to whom Mr. Watt's appeal was made, all of those learned persons, such as Maty, Nicholson, Thomson, Murray, Dalton, and others, who have with propriety been referred to as having, during the life-time of both Watt and Cavendish, or of one of them, assigned the priority to the former. But when, of those who have spoken since the death of both claimants, we find one great name after another,—DAVY, and HENRY, and ARAGO, and BROUGHAM, and DUMAS, and BERZELIUS, and BREWSTER, and JEFFREY, and LIEBIG, —illustrious umpires of more than European fame, devoted to various pursuits, scientific, legal, and literary, and whose judgments are destined to an enduring celebrity,—all deciding in favour of the priority of Watt over Cavendish; we feel that the decision to which The First Discoverer looked forward with sure and tranquil confidence, has at length emphatically been pronounced; that in the even hand of Justice the balance has at last descended; that Truth *is* great, and *has* prevailed over both the natural prejudices and prepossessions of time, and the less excusable bigotry of partisanship. And as, in the wonderful history of elemental Nature, by NEWTON, "*Qui* "*genus humanum ingenio superavit*," first was developed the magnificent idea of the COMPOSITION OF LIGHT, so it may safely be recorded that to WATT, the great subjugator of the power of steam, first occurred, and by him was first set forth, the no less novel, astonishing, and fruitful idea of the COMPOSITION OF WATER.

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* See Godson on Patents, pp. 27-30. The term "Inventor" is, of course, here used in the legal sense, of "one "that has found out something new."

† To Dr. Darwin, 24 November, 1789.

With one parting admonition we conclude all that it appears needful now to say on this subject. Dr. Faraday, unquestionably the most illustrious living representative of the chemical science of Great Britain, while he laments that "in the present day there is no lack of cases amongst philosophers in "which men poach on the ground preoccupied by others," expresses his hopes that "this case, as it now stands forth, "will be a warning to some; and assist in reviving and "restoring the moral and honourable feelings of those who "may, by circumstances, come hereafter into temptation."* A sentiment in which all true lovers of science, who desire to be no less just than they are wise and learned, will cordially concur, and which we commend to the attention of all others whom in a different way it may concern.

It may somewhat relieve the dullness of scientific discussion, and also present a more cheerful view of human nature than some other parts of "the water controversy" afford, if we offer such confirmation as our present researches enable us to do, of the late Mr. James Watt's assertion that his father, "after becoming in 1785 a Fellow of the Royal "Society, formed the personal acquaintance of Mr. Caven-"dish, and lived upon good terms with him."* In August of that year, it appears, Cavendish visited Birmingham and Soho, where he spent some time in examining the engine establishment, and conversing with Mr. Watt upon it:—and in October of the same year, Mr. W. wrote† as follows:—"When I was in London I was received very kindly by Mr. "Cavendish and Dr. Blagden, and my old friend Smeaton, "who has now recovered his health, and seems hearty. I "dined at a turtle feast with them and the select club of the "Royal Society; and never was turtle eaten with greater "sobriety and temperance, or more good fellowship. I dined "also at Mr. Cavendish's, who lives very elegantly, and gave "us a good English dinner. Among other company we had "the famous Peter Camper, the Anatomist, once Professor at "Franecker,‡ a fresh gigantic man of 64, that never had "sickness in his life except once. He is to come here before "leaving England." §

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* From a MS. letter of Dr. Faraday to the Editor, who has been kindly authorized in this manner to make its contents public.

Notwithstanding the epithet here applied by the guest,—a man of plain habits and simple tastes,—to the style of living practised at Cavendish's house, the hospitalities of that abode are usually admitted to have been neither numerous nor profuse. The "good English dinner" was probably the eternal *leg of mutton*, which, on days of unwonted festivity, made the cheer at that table of hungry science; but which, on one extraordinary occasion, when the company amounted to *six*, was known to have been multiplied by two, and thus to have formed a repast of legs of mutton,—like rainbows,—primary and secondary. The contrast must have been a striking one, between the nervous and shy chemist, "uttering a shrill cry

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* 'Correspondence of Mr. Watt on 'his Discovery of the Composition of 'Water,' p. iv.

† To Mrs. Watt, Birmingham, October 31st, 1785.

‡ In Friesland. Camper was born in 1722, and, in the same year in which he met Mr. Watt, was elected a member of the Academy of Sciences at Paris. He died in 1789; and is buried in St. Peter's Church, Leyden.

§ Which he accordingly did: as we learn from a letter of Mr. Watt to Mrs. Watt, dated Birmingham, November 3, 1785—"I had a visit of "Professor Camper yesterday: he is "a fine old fellow."

"as he shuffled quickly from room to room;"[*] and the thoughtful but active and animated engineer, with "voice "deep and low, in harmony with the weight and beauty of "his discourse; mirthful, temperately jocular,"[†] and with a manner marked, beyond that of all others, by "a fine expres-"sion of reposing strength and uninterrupted self-possession."[‡] We had formerly regretted, that neither Mr. Watt, nor, so far as we then knew, any one else, had left any record of Mr. Cavendish's "flow of soul" on the evening in question; but we have since discovered, in a pocket-book for 1785, under date of 21st October, in Mr. Watt's hand-writing, this entry; —"Dined at Mr. Cavendish's, topic Hugenian telescope." It may, however, be conjectured that at that interesting party the subject of the composition of water was not broached; and that the "best of elements" was discussed only in undecompounded and corporeal form, befitting the sobriety of a board over which Bacchus is understood *not* to have presided as the tutelary deity.

In point of convivial enjoyment, the other dinner mentioned in Mr. Watt's letter would appear, from his expressions, considerably to have excelled the entertainment supplied at Cavendish's eremitical abode. And we are not without other means of estimating the amount of good fellowship which habitually prevailed at those "noctes cœnæque "Deûm" of the club of the Royal Society. That distinguished mineralogist, M. Faujas de St. Fond, has devoted some pages of his 'Travels in Great Britain' to recording the scene he witnessed, and the impression it made upon him, when a few years later he partook of a like hospitality; and as, on the occasion of which he speaks, Sir Joseph Banks was President, Blagden Secretary, and Cavendish one of the party, and all of those three are among the persons of what we may term the drama of the discovery of the composition of water, we perhaps need not apologise for introducing some notice of that feast of scientific reason, which M. de St. Fond has minutely, and with evident relish, thus described.

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[*] Lord Brougham, 'Life of Cavendish,' p. 446.

[†] Lord Brougham, 'Life of Watt,' p. 389.

[‡] Lord Jeffrey, 'Character of Watt,' *infrà*.

At this "dinner of an academic club," which commenced at five o'clock, he says, "the dishes were of the solid kind, "such as roast beef, boiled beef, and mutton prepared in "various manners,—with abundance of potatoes and other "vegetables, which each person seasoned as he pleased with "the different sauces which were placed upon the table. "The beef-steaks and the roast beef were at first sufficiently "drenched by *large quantities of strong beer, called porter:* it "was drank out of cylindrical pewter pots, *which are, by some,* "*thought preferable to glasses, perhaps because they enable one* "*to swallow a whole pint at a draught.* This prelude being "finished," there appeared, "as if by magic, a number of fine "crystal decanters filled with the best port, madeira, and "claret." "Several glasses were distributed to each person, "and *the libations commenced on a grand scale,* in the midst of "different kinds of *cheeses, which, rolling in mahogany cases* "*from one end of the table to the other, provoked the thirst of* "*the drinkers.*" "The members of the club afterwards saluted "each other, one by one, with a glass of wine. According to "this custom, *one must drink as many times as there are guests,* "for it would be thought a want of politeness in England to "drink to the health of more persons than one at a time." M. de St. Fond had mentioned, in an earlier part of his account, that the club consisted of about forty members, each of whom had a right to introduce two, and the president a greater number of friends. He does not mention by how many the guests, and consequently the glasses of wine drank by each at this stage of the entertainment, fell short of the hundred and twenty to which that compotatory computation might amount. But, *qualis ab incepto,* the convivial narrative proceeds:—"*A few bottles of champagne soon put all the company in good humour.* The tea came next, with butter, "marmalade, and all its usual accompaniments: coffee followed, humbly yielding precedence to the tea, though it be "the better of the two. In France, we commonly drink only "one cup of good coffee after dinner; in England, they drink

" five or six times that quantity, of the most detestable kind. " *Brandy, rum, and some other strong liquors, closed this philo-* " *sophic banquet.*" And for the solid repast with all its fluid accompaniments,—" all this intolerable deal of sack,"—each of the guests paid " seven livres, four sols French money." With justice does the good M. Faujas remark " This was not " dear;" and he sympathetically adds " The great Corneille, " Molière, Despreaux, La Fontaine, and Racine, used to take " a bottle now and then in a tavern; and they were neither " the worse friends, nor the worse poets, for it."

Science, indeed, seems, at the symposium which he thus describes, to have appeared to M. de St. Fond in that form, " quæ, si oculis cerneretur, mirabiles amores, ut ait Plato, " excitaret sapientiæ!"* And, although the *sçavoir vivre* of the tavern in London may not have strictly exemplified the succulent doctrines of the 'Almanach des Gourmands,' or complied with all the gustatory directions of the 'Manuel 'des Amphitryons,' yet so highly was the honest Frenchman delighted with the lively but decorous gaiety which he had witnessed, as to have imagined that a similar system of " convivial and modest banquets" among the learned men of his own country might have averted some of the worst crimes of its regicidal revolution;—crimes, which the exalted but hapless names of Malesherbes, Bailly, Lavoisier, and Condorcet, recall to the horror and grief of humanity. "In France they " *now* order these things better;" and all who have enjoyed the privilege of sharing in the festive entertainments frequent among the men of letters and science in the metropolis of that great and polished nation, can bear testimony to the simple but elegant refinement, the warm-hearted hospitality, the love of the Muses and admiration of the Graces, by which they are distinguished. Let us indulge the hope, that the frequent recurrence of scenes so congenial to the wishes of M. Faujas, may ensure all those happy results which he fancied,—(perhaps not very unreasonably),—that he foresaw in their due observance!

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* Cic. De Off. I. cap. v.

CHAPTER XXIII.

PROPOSED UNIFORMITY OF WEIGHTS AND MEASURES — THE LUNAR SOCIETY — DR. DARWIN — PRIESTLEY — RIOTS AT BIRMINGHAM — MR. WATT'S JOURNEY TO PARIS AT THE REQUEST OF THE FRENCH GOVERNMENT — MACHINE OF MARLY — BLEACHING BY CHLORINE — INFRINGEMENTS OF STEAM-ENGINE PATENTS — TRIALS AT LAW — PARTIES TO THE ACTIONS — ARGUMENTS AGAINST AND FOR THE VALIDITY OF THE PATENT OF 1769 — NATURE OF THE EVIDENCE — J. BRAMAH AND T. TREDGOLD — VERDICTS IN FAVOUR OF THE PATENTEES — VALIDITY OF THE PATENT OF 1769 CONCLUSIVELY ESTABLISHED.

Mr. Watt's chemical studies in 1783 having led him, towards the end of that year, to make some calculations from experiments of Lavoisier and De La Place, and to compare them with others made by Mr. Kirwan, he wrote to the latter gentleman,* "I had a great deal of trouble in reducing the " weights and measures to speak the same language; and " many of the German experiments become still more diffi- " cult from their using different weights and different divi- " sions of them in different parts of that empire. It is " therefore a very desirable thing to have these difficulties " removed, and to get all philosophers to use pounds divided " in the same manner, and I flatter myself that may be " accomplished if you, Dr. Priestley, and a few of the French " experimenters will agree to it; for the utility is so evident, " that every thinking person must immediately be convinced " of it. My proposal is briefly this; let the

Philosophical pound	consist of	10 ounces,	or	10,000 grains.
the ounce	„	10 drachms,	or	1,000 „
the drachm	„	100 grains,	or	100 „

" Let all elastic fluids be measured by the ounce measure of " water, by which the valuation of different cubic inches will

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* 14th November, 1783.

" be avoided, and the common decimal tables of specific gra-
" vities will immediately give the weights of those elastic
" fluids.

"If all philosophers cannot agree on one pound or one
" grain, let every one take his own pound or his own grain;
" it will affect nothing except doses of medicines, which must
" be corrected as is now done; but as it would be much
" better that the identical pound was used by all, I would
" propose that the Amsterdam or Paris pound be assumed as
" the standard, being now the most universal in Europe: it
" is to our avoirdupois pound as 109 is to 100. Our avoir-
" dupois pound contains 7000 of our grains, and the Paris
" pound 7630 of our grains, but it contains 9376 Paris grains,
" so that the division into 10,000 would very little affect the
" Paris grain. I prefer dividing the pound afresh to begin-
" ning with the Paris grain, because I believe the pound is
" very general, but the grain local.

" Dr. Priestley has agreed to this proposal, and has referred
" it to you to fix upon the pound if you otherwise approve of
" it. I shall be happy to have your opinion of it as soon as
" convenient, and to concert with you the means of making
" it universal. * * * I have some hopes that the foot
" may be fixed by the pendulum and a measure of water,
" and a pound derived from that; but in the interim let us
" at least assume a proper division, which from the nature of
" it must be intelligible as long as decimal arithmetic is used."

" As to the precise foot or pound," he afterwards adds, in
writing to Mr. Magellan, "I do not look upon it to be very
" material, in chemistry at least. Either the common English
" foot may be adopted according to your proposal, which has
" the advantage that a cubic foot is exactly 1000 ounces,
" consequently the present foot and ounce would be retained;
" or a pendulum which vibrates 100 times a minute may be
" adopted for the standard, which would make the foot 14·2
" of our present inches, and the cubic foot would be very
" exactly a bushel, and would weigh 101 of the present
" pounds, so that the present pound would not be much
" altered. But I think that by this scheme the foot would

" be too large, and that the inconvenience of changing all " the foot measures and things depending on them, would be " much greater than changing all the pounds, bushels, gal- " lons, &c. I therefore give the preference to those plans " which retain the foot and ounce." Alas, at the distance of three-quarters of a century from such philosophical and practical proposals, the prospect of a universal system of weights and measures seems almost as remote as that of a universal language!

About the time when Mr. Watt presented to the Royal Society his memorable 'Thoughts on the Constituent Parts 'of Water,' the neighbourhood of Birmingham was remarkable for the number of kindred spirits, all devoted to the pursuit of natural knowledge, and filled with mutual esteem and affection, who there found profitable pleasure in each other's society. Besides Mr. Watt and Mr. Boulton, there were among that number Dr. Darwin, Dr. Withering, Mr. Keir, Mr. Galton, Mr. Edgeworth, and Dr. Priestley;—all of them luminaries not unworthy to revolve round Watt as their central sun, but also shining with more than merely reflected light. Priestley, who came to reside at Birmingham in 1780, and has repeatedly acknowledged the happiness he experienced in living near Mr. Watt, has thus noticed those monthly repasts of which his philosophical friends and himself partook at their respective houses in turn, and which became well known as the meetings of *the Lunar Society.* "I " consider my settlement at Birmingham as the happiest " event in my life; being highly favourable to every object I " had in view, philosophical or theological. In the former " respect I had the convenience of good workmen of every " kind, and the society of persons eminent for their know- " ledge of chemistry; particularly Mr. Watt, Mr. Keir, and " Dr. Withering. These, with Mr. Boulton and Dr. Darwin, " who soon left us by removing from Lichfield to Derby, " Mr. Galton, and afterwards Mr. Johnson of Kenilworth and " myself, dined together every month, calling ourselves *the* " *Lunar Society*, because the time of our meeting was near "the full-moon,"[*] "in order," as he elsewhere says, "to "have the benefit of its light in returning home." From an invitation from Mr. Watt to Mr. Wedgwood to attend one of the dinners of the Society, we learn that it was customary for the philosophic *convives* "to dine at two o'clock, and not to "part till eight in the evening."

Mr. Watt, in writing to Dr. Darwin to remind him of his engagement to attend another of those friendly meetings, at once social and scientific, gives a lively bill of fare of the subjects proposed for the consideration of the party;—some expressions used in which, viz., "it is to be determined "whether or not heat is a compound of phlogiston and empyreal air," "what light is made of, and also how to make "it,"[†] as well as the still more curious ones of Darwin's reply, "I can tell you some secrets in return for yours, viz., "that atmospheric gas is composed of light and the earth of "water (aqueous earth),—*that water is composed of aqueous* "*gas, which is displaced from its earth by oil of vitriol,*"[‡]—may be held to have foreshadowed, with more or less distinctness, those researches which ended in the discovery of "what water is made of," and also, as the discoverer quaintly expresses it, "how to make it."[§] Thus to Darwin, the general design of whose somewhat fantastic but often elegant poetry was, as he informs us, "to enlist Imagination under "the banners of Science," may now be assigned some of the credit of having been a pioneer in the march towards that great discovery:—a merit, however, which he never claimed for himself, both he and Mr. Watt having apparently given, at the time, no more than a passing attention to the shot thus fired, probably at random, but with a curious approximation to the mark which was afterwards effectually hit. For the speculation,—whether we call it imagination or science,—

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[*] 'Memoirs of Dr. Priestley, by 'himself,' p. 97. 1806.

[†] Mr. Watt to Dr. Darwin, Birmingham, January 3rd, 1781; 'Mechanical Inventions of Watt,' vol. ii. p. 123.

[‡] Dr. Darwin to Mr. Watt, Jan. 6, 1781; 'Mechanical Inventions of 'Watt,' vol. ii. p. 124.

[§] Mr. Watt to Mr. Fry of Bristol, p. 329, *suprà*.

that water was a composite body at all;—that it was, in any way, composed of a "gas;"—which gas was "aqueous, dis-"placed from its earth by oil of vitriol," (a wonderfully fair description of the hydrogen of later days), was, no doubt, a "secret" worth communicating, even though nothing was said either of another gas, or of explosion by an electric spark. It is indeed difficult to judge how far it may not have been one of those early seeds of the great discovery, which, afterwards germinating in the sagacious mind of Mr. Watt, bore their first-fruits in his celebrated conclusions communicated to Dr. Priestley and the Royal Society in 1783; and which were afterwards followed by the second and third harvests which Cavendish and Lavoisier respectively reaped,—or *gleaned.*

That Darwin never dreamt of claiming for himself, on the strength of such expressions, any share of the credit of the real discovery as to the compound nature of water, and its true constituents, appears from his poem, 'The Botanic 'Garden;' where, after describing the process of the formation of that fluid,—

> " Nymphs! your bright squadrons watch with chemic eyes
> " The cold elastic vapours as they rise;
> " With playful force arrest them as they pass,
> " And to PURE AIR betroth the *flaming* GAS:"—

he only says,—"Until very lately, water was esteemed a "simple element, nor are all the most celebrated chemists of "Europe yet converts to the new opinion of its decomposi-"tion. M. Lavoisier and others of the French school have "most ingeniously endeavoured to show that water consists of "pure air, called by them oxygen, and of inflammable air, "called hydrogen, with as much of the matter of heat, or "calorique, as is necessary to preserve them in the form of "gas;" and he mentions that "The history of the progress "of this great discovery is detailed in the Memoirs of the "Royal Academy [of Sciences] for 1781, and the experi-"mental proofs of it are delivered in Lavoisier's 'Elements of "'Chemistry.' The results of which are that water consists "of eighty-five parts, by weight, of oxygen, and fifteen parts,

" by weight, of hydrogen, with a sufficient quantity of calo-" rique."* And again in a subsequent note, where, speaking of "the present important discovery of the production of " water from pure air, or oxygen, and inflammable air, or " hydrogen," he says that one might be tempted to believe, from allegorical interpretations of the old mythology, "that " the very ancient chemists of Egypt had discovered the " composition of water, and represented it in their hiero-" glyphic figures before the invention of letters."† The subject is also referred to in another of Dr. Darwin's works, viz., his 'Phytologia;' where he says, "According to the theory " of M. Lavoisier concerning the composition and decomposi-" tion of water, there would seem another source of thunder-" showers; and that is, that the two gases termed oxygen gas " or vital air, and hydrogen gas or inflammable air, may exist " in the summer atmosphere in a state of mixture, but not of " combination; and that the electric spark, or flash of light-" ning, may combine them, and produce water instanta-" neously."‡ But nowhere does the highly imaginative and well-informed Doctor appear to have sought to associate his own name with the discovery on which he bestows such deserved admiration; and, indeed, the "composition" of which he writes, whatever may have been the force or the weakness of the impression which the idea of it had made on his mind, must be viewed as rather a transmigration from one substance into another, than as a compounding of two substances into one. Still, the "secret" he announces will be considered as no uninteresting addition to the literature of the late "water controversy;" *valeat quantum valere potest.*

The Lunar Society lost one of its most active and valued members by the disgraceful riots which in 1791 had the effect of driving Priestley from his home; when his house, library, chemical apparatus, and furniture were destroyed by the cowardly violence of the rabble. On that occasion the extraordinary spectacle was presented, of an ignorant and brutal mob in England arming themselves against the partisans of democratic lawlessness in France. "The affair originated," wrote Mr. Watt to his friend M. De Luc,* "from "some gentlemen very foolishly celebrating the French revo-"lution by a dinner on the 14th. They were warned that "some tumult might ensue, and advised against it; how-"ever, some of them met, were insulted as they went in, "and, therefore, dispersed by five o'clock. About eight "o'clock a mob assembled, broke the windows of the hotel "where the company met, pulled down two dissenting meet-"ing-houses, then Dr. Priestley's house, which they razed to "the ground, (he and family made their escape in time); "they then destroyed a very good house in town, and from "that proceeded to destroy some others in town, and some "of the best houses in the country, mostly belonging to dis-"senters, they say to the number of ten or fifteen, and to the "amount of above 100,000*l.* Then was the sovereignty of "the people established in full authority for three days and "nights! Quiet subjects were panic-struck; and, after some "feeble efforts to establish peace, people submitted quietly "to their fate. We, on our part, finding there was no like-"lihood of any other protection, applied to our workmen, "convinced them of the criminality as well as imprudence "of joining the mob, and kept them all at home, procured "some arms, and had their promise of defending us and "themselves against all invaders.

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* 'Botanic Garden,' part i. canto iii. l. 200-204; and note, vol. i. p. 152, ed. 1799.

† Ibid., p. 156, note.

‡ 'Phytologia, or the Philosophy 'of Agriculture and Gardening,' p. 313, ed. 1800.

"Though our principles, which are well known, as friends "to the established government, and enemies to republican "principles, should have been our protection from a mob "whose watchword was *Church and King,* yet our safety was "principally owing to most of the dissenters living on the "south of the town; for after the first moments they did not "seem over nice in their discriminations of religion or prin-"ciples. I, among others, was pointed out as a Presbyterian, "though I never was in a meeting-house in Birmingham, and

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* 19th July, 1791.

" Mr. B. is well known as a Churchman. We had everything " most portable packed up, fearing the worst; however, all is " well with us. It must be observed to their credit, that they " neither killed nor maltreated any of the sufferers, except " such as opposed them by violence, among whom they dealt " some civil knocks by bludgeons. Some military arrived on " Sunday night, since which there has been no rioting in the " town, and we hope they are dispersed."

Even three months later, when Dr. Priestley proposed paying a short visit to Birmingham for the purpose of taking leave of his friends and congregation there, Mr. Watt thought it necessary still to write to him recommending caution and delay. Afterwards, when the Doctor had removed, first to Clapton, and then to Northumberland in America, his friends " contributed," as he said, " to set up a broken philosopher" in his state of exile; and among the useful articles which in his new laboratory recalled the pleasant memories of Soho, were a digester, a chemical lamp, a number of duplicates from Mr. Boulton's collection of minerals, and what the worthy and venerable philosopher calls " the noble present of a furnace, " and other apparatus for making large quantities of air;" which he found " invaluable," and much more convenient than anything he had ever possessed before.

As for the Lunar Society, we believe that it continued to exist at the beginning of the present century; but the last particular notice we have been able to find of that amicable association occurs in a dedication by Priestley, in 1793, (which was two years after his retirement from Birmingham), of one of his works,* to his "valued friends, the members of the " Lunar Society at Birmingham;" in which he says, "There " are few things that I more regret, in consequence of my " removal from Birmingham, than the loss of your society. " It both encouraged and enlightened me; so that what I did " there of a philosophical kind ought in justice to be attributed almost as much to you as to myself. From our " cheerful meetings I never absented myself voluntarily, and

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* 'Experiments on the Generation of Air from Water,' London, 1793.

" from my pleasing recollection they will never be absent. " Should the cause of our separation make it necessary for " me to remove to a still greater distance from you, I shall " only think the more, and with the more regret, of our past " interviews." * "Philosophy," he adds, " engrossed us wholly. " Politicians may think there are no objects of any conse- " quence besides those which immediately interest *them.* But " objects far superior to any of which they have an idea en- " gaged our attention, and the discussion of them was accom- " panied with a satisfaction to which they are strangers. " Happy would it be for the world if their pursuits were as " tranquil, and their projects as innocent, and as friendly to " the best interests of mankind, as ours." Finally, he concludes by earnestly committing them all, though in religious persuasion differing from himself, " to the protection and " blessing of that Great Being, *whose we are, and whom,* I " trust," he says, " *we all serve;* and who established that " course of nature which is the object of our common investi- " gation;" and then he prays, " with the greatest esteem and " affection," for a happy reunion with them all in another state of being.

Would to God that the fervent pursuit of science had in all cases the effect of producing a temper of mind equally calm, equally devout, and therefore equally happy!

In 1786, Mr. Watt and Mr. Boulton proceeded to Paris, on the invitation of the French Government, to meet proposals for their erecting steam-engines in that country under an exclusive privilege. In particular, they were to suggest improvements on the great hydraulic machine of Marly; that gigantic specimen of a race of mechanical megalosaurians, now nearly extinct, of which Belidor has given a striking description, but which he introduces by the eulogy,—a very questionable one, as most of our readers know, where machinery is concerned,—" il ne paroît pas que l'on ait jamais

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* For another friendly but brief allusion to the same Society, see Priestley's letter to Messrs. Boulton and Watt, 17 October, 1801, 'Mechanical Inventions of Watt,' vol. ii. p. 277.

"exécuté de machine *qui ait fait autant de bruit* dans le "monde que celle de Marly."*

The Machine of Marly was erected at the village of that name upon the Seine, by Rennequin of Liege, for Louis XIV. in 1682, to raise water for the town and water-works of Versailles. This was effected by means of fourteen large water-wheels, and a series of pumps, pipes, cranks, and rods, remarkable for their complexity and the noise they made in working. The improvements suggested on this machine were not carried into effect; in consequence of financial difficulties, and the dismissal of the ministry. Since then, a steam-engine has been erected by the French to do part of the work; and two of the wheels, with improved apparatus, are all that remain of this cumbersome machinery. It is amusing, in the present state of hydraulic science, to read an account of the Machine of Marly, such as is given in Desaguliers:—"*When he,*" says that writer, "*that comes to* "*take a view of the engine at Marly, sees it cover a mile of* "*ground in length, and the breadth greater than that of the* "*whole river Seine,—he cannot but look upon it as a stupendous* "*machine.* * * * * *It is said that the Machine at Marly* "*cost above eighty millions of French livres, which is above four* "*millions of pounds sterling. Some of the largest of our fire-*"*engines, at present* [1744] *in use in England, will raise as* "*much water to the same height, and not cost above ten thousand* "*pounds.*" † The Marquis de Custine calls that ancient machine the same thing in mechanics, as of old the Inquisition in Spain was in politics; ‡ "the venerable machine of "Marly," says Mr. Watt, "they now consider as much the "disgrace as it once was [considered to be] the honour of the "nation;" and therein, also, let us hope that De Custine's parallel may now hold good.

This journey was not undertaken without proper precautions being used to prevent it being supposed that the manufacturers of the new steam-engines were desirous of pushing their own interests in any way that might prove prejudicial to their country; " I think," Mr. Watt wrote to Mr. Boulton, " if either of us go to France, we should first wait upon Mr. " Pitt, and let him know our errand thither, that the tongue " of slander may be silenced, all undue suspicion removed, " and ourselves rendered more valuable in his eyes, because " others desire to have us!" The principal objects of their visit were frustrated by the political circumstances of the time; and although " perfectly sensible of the honour which " might be acquired by such a job as Marly," Mr. Watt was also fully aware that it would be attended with much labour and vexation, and he felt " by no means sure of the " profit." But the English engineers had a very agreeable journey; and a most flattering reception in Paris from the ministry, who seemed much disposed to employ them in the line of their business, as engine-makers, in France. They however absolutely refused to engage in any such manufacture, as contrary to the interest of Great Britain. They had also the satisfaction of making the acquaintance of most of the eminent men of science of whom the great capital of France had then to boast, as Lavoisier, La Place, Monge, Berthollet, De Prony, Hassenfratz, Fourcroy, Delessert, and others; with most of whom they afterwards maintained a frequent and most friendly correspondence. Mr. Watt gaily described himself as having been on this occasion "drunk " from morning till night with Burgundy and undeserved " praise;" although greater temperance than his probably never partook of the entertainments which enlivened the scientific morning or evening, nor were the panegyrics of the great ever bestowed upon one who received them with more perfect modesty and self-distrust.

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* Desaguliers, Annot. upon Lecture XII. of his 'Course of Experimental Philosophy.'

† Ibid.

‡ 'L'Espagne sous Ferdinand VII.' Tom. ii. p. 67, ed. 1838.

It was then that Berthollet communicated to Mr. Watt his discovery of the new method of bleaching, by means of what was at that time termed the dephlogisticated acid of sea-salt; and exhibited the process in the presence of a number of spectators, among whom were Mr. Watt and Mr. Boulton. On their return to England, those gentlemen mentioned to Mr.

Pitt that M. Berthollet was in possession of such a process, in the view of obtaining for him a parliamentary reward, or exclusive privilege in Great Britain:—an object, however, which proved to be so difficult of attainment, that M. Berthollet subsequently renounced any lucrative views connected with his discovery, in this country. He then gave permission to Mr. Watt to communicate it to his father-in-law, Mr. Macgregor, who was enabled to employ it in his trade, along with several new improvements of Mr. Watt's invention, the results of a long series of experiments. "In relation to the in-" "ventor," says Mr. Watt,* "he is a man of science, a member "of the Academy of Sciences at Paris, and a physician, not "very rich, a very modest and worthy man, and an excellent "chemist. My sole motives in meddling with it were, to "procure such reward as I could to a man of merit who had "made an extensively useful discovery in the arts, and "secondly, I had an immediate view to your interest; as to "myself, I had no lucrative views whatsoever, it being a "thing out of my way, which both my business and my health "prevented me from pursuing further than it might serve for "amusement when unfit for more serious business. Lately, "by a letter from the inventor, he informs me that he gives "up all intentions of pursuing it with lucrative views, as he "says he will not compromise his quiet and happiness by "engaging in business; in which, perhaps, he is right: but "if the discovery has real merit, as I apprehend, he is cer-" "tainly entitled to a generous reward, which I would wish, "for the honour of Britain, to procure for him; but I much "fear, in the way you state it, that nothing could be got "worth his acceptance." The process was also practised on a large scale, (in consequence of similar information communicated to them by the original inventor), by Messrs. Henry, and Messrs. Baker and Co., of Manchester; and so greatly did the new improvement succeed, that it soon afterwards appeared, on the occasion of a trial as to the validity of a patent for preparing the material used, that one bleacher at

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* To Mr. Macgregor, 27th April, 1787.

Manchester bleached at the rate of a thousand pieces of muslin, (of thirty yards each), every day, and that the goods were only three days in hand until they were completely finished. Another declared that the saving of potash which e effected by using the new process, amounted to above 000*l.* in the course of little more than a year.

But we must turn from such *délassements* as scientific feasts and philosophical tours, by which the ordinary routine of Mr. Watt's laborious life was occasionally,—but only too seldom, —pleasantly diversified, to a far less agreeable but more compulsory occupation in which a considerable portion of it was now unavoidably consumed. It has long been the hard fate of most inventors, if their inventions are of any real value, to be assailed by unworthy and surreptitious rivals; and Boulton and Watt formed no exception to the too great universality of this rule. For very many years, although seriously injured by the piratical practices of their opponents, they submitted to them, if not in silence, at least without openly punishing them by law. The consequence was, that in course of time, engines on the principle of separate condensation, and with such other particulars of the Soho construction as could be picked up by bribery of workmen and other clandestine means, began to be erected. It is true, that of such engines, which were of very erroneous proportions and defective manufacture, the performances were usually far from being successful. Some, like Hornblower's at Radstoke, were asthmatic, "obliged to stand still once every ten minutes, "to snore and snort;" [*] "when they have got a very strong "steam, it will make 21 strokes in three minutes, but then "comes to rest, and must stand five minutes before it gets "strength enough to make another stroke, and all the while "they must fire away as hard as ever they can, otherwise it "will not work at all." [†] Some were like Evans's mill, which "was a gentlemanly mill: it would go when it had nothing "to do, but refused to do any work." The greatest achievement which some others succeeded in effecting, was to burst their own boiler, or break their own machinery to pieces. But the manifestation even of such energy was rare among them; of all " the bodily presence,"—so, at least, thought Mr. Watt, —" was weak," and the work " contemptible." Still, even such imperfect and really useless machines injured the fair traders, by attracting customers through a specious though deceptive show of cheapness; while on the other hand, their numerous faults, and the annoyances which they caused, tended to excite a prejudice even against the Soho engines, which were often ignorantly classed along with them under the general category. At last, it was deemed right, as the least of two evils, to try whether the exclusive privilege could not be compulsorily and penally established against those who had infringed it; and the wide field of litigation was therefore deliberately, though reluctantly, entered upon.

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[*] Mr. Watt to Mr. Boulton, 5th September, 1783.

[†] Mr. Watt to Mr. G. Hamilton, 22 September, 1782.

The legal proceedings, both in equity and at common law, which now became necessary, were numerous; and it is painful, even at this distance of time, to contemplate the mass of litigation through which, in mere self-defence, the patentees were compelled to struggle. A bill of costs, sent in by one firm of solicitors in London, for their outlay and professional services in matters connected with the various infringements, has been preserved, and is now before us: amounting, for the short space of the four last years of the time to which the extension of the patent was limited, viz. from 1796 to 1800, to between five and six thousand pounds![*] This was unquestionably a fearful tax;—a burden grievous to be borne by the successful discoverer in science, and his enterprising associate, in seeking the final, though tardy, enforcement of justice!

But that pecuniary amount, large as it is, and representing, as it probably does, not much more than one half of the whole expense caused by the proceedings of their opponents, cannot for a moment be viewed as equivalent to the mental and bodily labour, the constant anxiety and frequent vexation, which such opposition entailed; all of which were aggravated, in a high degree, by the comparatively unsettled state in which the law of England then remained on the subject of patents.

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[*] Long afterwards, (in 1818), when speaking of an account, the charges in which were enormous, Mr. Watt said that " *it would not have disgraced* " *a London solicitor*." The experience of many of our readers may have taught them to understand the full force of this remark; although, happily, there are honourable exceptions to the too general rule.

It is melancholy to reflect that, in any case, that leisure and tranquillity of a philosophic mind which might have produced further discoveries of refined beauty or extensive utility, should be sacrificed and consumed in resisting the invasion of the powerful, or defeating the fraudulent chicanery of the covetous. And when to this reflection is added the further and still more grievous knowledge that such resistance may not, and in the chances of human affairs cannot, always meet with success, the peculiar hardship of the lot of many a deserving person, whose genius has, unfortunately for himself, distinguished him among his fellows, will at once become apparent. Thanks to those learned and indefatigable labours in the cause of law reform in this kingdom, with which must ever be associated in honour the name of BROUGHAM, such occurrences, instead of being the common rule, can henceforth be only the rare exception; and it is not easy to estimate the amount of benefit which has thus been obtained for the ingenious, but possibly humble, poor, and friendless inventor, by one who could alike compassionate his necessities, and sympathise with his difficult pursuit of science.

The advancing years of both Mr. Watt and Mr. Boulton, of whom the expiration of the patent found the one approaching, and the other already past, his threescore and tenth year, made them both feel more sensibly the severity of so distasteful a conflict; which, although conducted with both skill and determination on their own part, was latterly intrusted chiefly to the management of their sons, Mr. James Watt, junr., and Mr. M. Robinson Boulton. "In the whole affair," writes Mr. Watt to his old friend, Dr. Black,* "nothing was "so grateful to me as the zeal of our friends, and the activity "of our young men, which were unremitting."

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* 15 January, 1797.

Two trials in particular there were, in which Mr. Watt's principal invention, and the patent granted for its exercise, became the subject of full and elaborate discussion; and which, both at that time and since, attracted too much attention to be at present unnoticed by us. Our remarks, however, on this part of our subject need be few, as further information on the various points noticed in the course of the arguments delivered, whether at the bar or from the bench, may be found in the reports of the opinions of the Judges, taken in short-hand at the time, and printed in a former work.*

In both of those causes Messrs. Boulton and Watt were the plaintiffs. The defendants were, in one of them, a person of the name of Bull; and, in the other, Messrs. [Jônathan] Hornblower and Maberly. "Mr. Bull," as was mentioned by Mr. Sergeant Adair, (one of the counsel for the plaintiffs), in introducing him to the notice and acquaintance of the jury at the trial, "was an officer,—if he might dignify it by that "epithet,—known, in all places where fire is used, and to be "mended, raked, or stirred, by the name of *a stoker*." And by having been employed by Boulton and Watt in that honourable capacity, and afterwards as an assistant engine-tender, he gained that acquaintance with the construction of their engines, through which he ultimately sought to deprive them of their patent rights. The cause of "Boulton and Watt "*v.* Bull," was tried in the Court of Common Pleas on the 22nd of June, 1793, by a special jury, before Lord Chief Justice Eyre. Among the witnesses on the side of the plaintiffs were De Luc, Herschel, Lind, Southern, Mylne, Cumming, Murdock, More, Rennie, and Ramsden; and when their counsel rose to reply to the evidence adduced for the defence, the foreman of the jury said that the jury were already perfectly satisfied. The verdict was for the plaintiffs, subject to the opinion of the Court as to the validity of the patent. On the 16th of May, 1795, the special case came on for judgment; when the opinions of the Judges were equally divided.

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* See the Appendix to the 'Mechanical Inventions of Watt,' Nos. V. and VII., vol. iii. pp. 164-207, and 252-292.

For the patent were Lord Chief Justice Eyre, and Mr. Justice Rooke; *against* it, Mr. Justice Heath, and Mr. Justice Buller. Mr. Boulton, dining with the last-mentioned Judge shortly before the opinions were delivered, and having some idea of the view his Lordship was supposed to be likely to take of the points of law, gaily alludes to that learned person, when dispensing the hospitalities of his table, as "*dressing with* "*flowers the victim he is preparing to sacrifice.*" About the same time, so multifarious were the questions which the legal acumen of the counsel and Judges had raised concerning the patent and its infringement, that Mr. Watt writes, "Since I "have been so much among the doubting limbs of the law, "it is impossible to come to a conclusion upon any subject!"

Of the two defendants in the second cause, it was with perfect fairness stated at the trial that Mr. Maberly supplied the purse, and Mr. Hornblower the ingenuity, requisite for the infringement; and further, with a just severity, that Mr. Hornblower derived his knowledge and ingenuity undoubtedly from the most respectable source he could have derived them from, because he derived them from the ingenious inventor of the steam-engine himself, having acted for a considerable time, like Mr. Bull, in the employment of Messrs. Boulton and Watt. He was one of a numerous band of Hornblowers,— "Horners," or "Trumpeters," as they were sometimes called,— who seem to have followed mechanical and piratical pursuits under names partaking of an odd unanimity of patriarchal alliteration. There were Jonathan, and Jethro, and Jesse, and Jabez the elder, and Jabez the younger. Jonathan, an engineer, "a coppersmith," says Mr. Watt, "who, like Alex-"ander of that trade, hath done us much harm;" Jethro, a working engineer; Jesse, an engineer; Jabez the elder, an engineer, the brother of Jesse, and a defendant in this action. Finally, Jabez the younger, the son of Jabez the elder; and of him the description given is, that "*he calls himself* an "engineer." Of the history of those people, beyond their interference with the engines and patents of others, we know little; but it is not creditable to the prudence and industry of that particular Hornblower who was associated with Mr.

Maberly, that within a very few years after the close of the litigation, he was almost starving, a wretched prisoner in the King's Bench. Even then, his animosity against his former patrons had not ceased,—

> "Still in their ashes lived his wonted fires,"

and they blazed forth in a sort of tract or memoir on the steam-engine, printed in Dr. Olinthus Gregory's 'Treatise on 'Mechanics,' in 1807. That paper, although it may well appear not to have deserved any such notice, met with a crushing demolition in an article in the 'Edinburgh Review,'* which is understood to have proceeded from the pen of Professor Playfair, and was at the time termed his *Olynthiac Oration.*

The cause of "Boulton and Watt *v.* Hornblower and "Maberly," was tried in the Common Pleas on the 16th of December, 1796, and, like the previous case, by a special jury, before Lord Chief Justice Eyre. The verdict was, again, for the plaintiffs; and the proceedings on a writ of error subsequently brought, had only the effect of affirming that result by the unanimous opinion of the four Judges before whom it was argued, (as it was most ably and fully), on two several occasions.

The arguments against the validity of the patent, offered by the defendants in the action, (the plaintiffs in error), in the Common Pleas, were principally drawn from alleged objections to the sufficiency of the specification of 1769. And it must here be observed that the statute continuing the benefit of the letters patent, (which, having been granted for fourteen years from the 5th of January, 1769, would otherwise have been determined, by length of time, previous to the date of the action), provided that every objection in law competent against the patent should be competent against the statute, in case the patent ought not to have been granted: on grounds, namely, of prior invention and public use, or of the specification not complying with the conditions required by the statute (21 Jac. I., cap. iii.). But for such a proviso, objections to the validity of the patent, founded on the alleged insufficiency of the specification, could not have been listened to. It was, however, contended on the part of the infringers;—

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* 'Edin. Rev.,' vol. xiii. p. 311-333.

1. Generally, that the description of the engine given in the specification was not sufficient to put the public in possession of the best mode of making such engines on the newly invented principles, so as to entitle the patentee to the benefit of the monopoly, which the policy of the law prescribes shall be granted and secured only on condition of that being done.

How far this objection was or was not well founded, became, of course, matter of evidence for the jury; and while among the witnesses for the plaintiffs there was an unanimous concurrence of opinion as to the sufficiency of the description given in the specification, even those called by the defendants were, with few exceptions, also obliged to admit it. The exceptions* were some three in number, and the contrary nature of their testimony was at once accounted for, either by the interest they had, as being themselves infringers, to overthrow the patent, or by their inferior skill in their business as mechanics. On the one side were called intelligent men, who proved, that even from far less aid than was supplied in the specification, they actually had constructed steam-engines on the patented principle. On the other side, as it was well remarked at the trial, appeared "*blockheads, who* "*swore, with perfect veracity, that they could not do it!*"

A curious and interesting proof of how clearly the novel idea of condensation in a separate vessel could be presented to the mind of any one accustomed to consider mechanical subjects in a practical point of view, even when unaccompanied by anything like the fulness and clearness of the specification, was supplied by Mr. Robison in the following anecdote, which was understood at the time to have had a decisive effect on the minds of the Court and Jury:—

"In the year 1770," says Professor Robison, "I went to "Russia, to take the direction of the Imperial Academy of "Marine in that country. My house was adjoining to the

“ bason into which the docks of Russia were drained; the “ water was drawn out by two expensive windmills; it “ occurred to me that a steam-engine would answer the purpose “ better; and, as that country was at a great distance “ from pit-coal, it occurred to me that Mr. Watt's engine “ was the best. I recommended the Admiralty College to “ erect a steam-engine; this occasioned a good deal of conversation “ between me and the gentlemen of science in that “ country, particularly a Mr. Model, the Court apothecary, a “ gentleman of great reputation, and one of the first chemists “ of the age, whom I had instructed in the doctrine of latent “ heat. I wrote to Mr. Watt, desiring him to undertake the “ erection of an engine. Mr. Watt, with that liberality which “ is natural to him, declined interfering in it. The expression “ of his letter was, ‘I think you are fully able to conduct “ ‘ that project, and it will do you credit in the country where “ ‘ you are.’ The day that I received this letter, I went to “ drink tea with Mr. Model; and found sitting with him Mr. “ Æpinus, a gentleman no less eminent for his beautiful “ theory of magnetism and electricity. I mentioned Mr. “ Watt's genteel declinature, and also a passage of his letter, “ in which he said that by admitting steam to press down the “ piston, its want of perfect tightness was not so hurtful as “ appeared at first sight, because the steam which got past “ would only be lost, but would not choke the engine. Model “ broke out into an exclamation, confirming what I said. “ Æpinus did not see the force of what we said, and Model “ took out his pencil to make a sketch which would explain “ it to him. Not readily finding a bit of paper, I pulled a bit “ out of my pocket, on which he made a sketch. This happened “ to be an official report, which I had that day received “ at Cronstadt, and which I kept with many things of this “ kind, and they came home with my other papers. I “ submit it to the inspection of the Court, and presume it “ will be acknowledged as a convincing proof that Mr. Model “ completely understood Boulton and Watt's method; and “ that much less information than is given in the specification “ is sufficient for enabling an intelligent engineer to "erect an effective engine, or to comprehend Mr. Watt's "principles."

2. It was objected, secondly, in particular, that the mode of condensation, (by injection of a jet of cold water), was not specified.

But as this mode was familiarly known to all engineers, and even to most common mechanics, to have been ordinarily practised in Newcomen's engines, the repetition of it by Mr. Watt in his specification was quite uncalled for; no departure from the former practice, in that particular, being intended by him to be adopted.

3. That the relative proportions which the condenser should bear to the cylinder, and which the air-pump should bear to the condenser, were not specified, so as to render it unnecessary to resort to experimental trials, in the construction of engines on the new principles.

On this head, it was readily shown that it was not requisite, according to any fair interpretation of the law, that the specification should describe the proportions of the various parts of an engine so that any person whatsoever might, without previous instruction as an engineer, be thereby enabled at once to construct a perfect steam-engine; that it was quite sufficient if it gave the information needful for such as had both received some previous education, and had some just right to be regarded as engineers; that the exact proportions of either the condenser or the air-pump were quite immaterial to the satisfactory performance of the engine, provided only they were large enough to do the usual work of condensation and pumping; and that the magnitude proper for each of them could not fail to be known to all who possessed the amount of previous knowledge required for such business before the new invention was made. "It is not material," said Lord Kenyon, "whether the condenser shall be circular, square, "octagon, decagon, or what shape it shall be." "They quarrel "with us," said Mr. Rous, in his very able speech in the Court of King's Bench, in 1799, "for not giving a form of a "condenser. Neither form, nor size, nor position of the con-"denser is material. To have specified these would have "been to deceive. When the valve is opened, the steam, "from its elastic nature, escapes, and is condensed. If there "be any choice as to form, size, or position, these must "depend on the local means of keeping the condenser cold; "and when the artist is told that it must be kept cold, he "has every information on these heads which an artist can "require. Nothing more is now to be done but to get rid of "the air and elastic vapour, which cannot be removed by the "means before employed. This Mr. Watt directs us to "extract by a pump, worked by the engine, or otherwise, at "the pleasure of the artist. To complete the invention of "Mr. Watt, it was only necessary that this vapour should not "be suffered to accumulate. The common mode of doing "this, is to suspend the pump to the working beam of the "engine. I presume it will not be disputed, that the con-"denser and the pumps are tangible and vendible substances. "As to the perfection of this part of the invention, I cannot "demonstrate it to be equal to the perfection of the other "part, by the bare inspection of the specification. I must "refer my adversary to the testimony of witnesses, and the "evidence of the gauge annexed to the engine. From these "he will learn, that the exhaustion is nearly equal to that of "the air-pump, and, consequently, that all sensible resistance "to the action of the piston is removed."*

4. That of the various substances specified to be employed instead of water, to render the piston or other parts of the engines air and steam-tight, viz. "oils, wax, resinous bodies, "fat of animals, quicksilver, and other metals in their fluid "state," only one, (the fat of animals), was useful and economical in practice; and quicksilver, in particular, by corrosion and amalgamation, would injure any parts of the engine that might happen to be made of brass, to which it might get access.

There was evidently nothing in this objection deserving notice; as it was pretty certain that if any one of the substances specified was both cheapest and best, (as was said to be the case with mutton suet), *that* would soon be adopted, to the exclusion of the rest. As for the argument from the *quicksilver,* all mechanics at all acquainted with their business knew very well that that metal ought not to be applied to any brass work; and the Chief Justice could not help observing, that so *mercurial* an objection was scarcely to be considered as a subject for grave discussion.

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* Appendix to 'Mechanical Inventions of Watt,' No. VI. p. 232.

5. That no annexed drawing or model of the new engine was lodged with the specification.

Unfortunately, the numerous piracies that were successfully practised, showed but too forcibly, that no drawing or model was requisite to enable counterfeits of the new engine to be made. The fact was, that either drawing or model was not only quite unnecessary, and, from the endless variety of forms in which the invention might be applied, quite useless; but it might really have injured the efficacy of the patent by limiting the extent of its application. For it must always be remembered, that the invention was not, (as the infringers tried to represent it), of a new engine, but of a new method of saving fuel, by condensing the steam in a vessel apart from the cylinder. That separate condensation was the thing patented, in whatsoever form, or to whatsoever engine it might be applied; although the best mode of carrying out the principle, by valves, alternate communication, &c., was clearly pointed out, so as to be intelligible to all engineers or mechanics of ordinary capacity and education in their trade. " We called," said Mr. Rous, " all the most eminent theorists, " and practical engineers of all descriptions, who swore that " to construct the engine from this description was so perfectly easy, that no man of tolerable skill in his profession " could mistake." The allegation of the defendants on this head was also triumphantly refuted by the remarkable circumstance given in evidence by Professor Robison, which has been already cited;* as well as by the fact, that " another " engineer, who superintended twelve of Newcomen's engines " in Yorkshire, under a misapprehension respecting the time

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* See pp. 407-409, *suprà.*

" at which the patent would expire, had actually formed and " prepared all the parts, which have since been used with " complete success."*

"I know," adds Professor Robison, "that it has been " repeatedly objected to this opinion of men of science con" cerning the sufficiency of the specification, that Mr. Watt's " own accounts are in opposition to it. He had to encounter " many difficulties before he perfected his machine, even after " obtaining his patent. I know this well. But this was " chiefly in subordinate parts of the undertaking. I firmly " believe that the great principles were as perfect in his mind " in a few hours, as they are at this day; and that the phy" sical parts of the problem were as completely solved by his " first model, as they are now by his best engines. But when " Mr. Watt was engaged in bringing the contrivance to per" fection, he wished to perfect every part. He who wished " to make his engine not only the best, but the cheapest in " the world,—he struggled long, in opposition to his own " judgment, at Dr. Roebuck's instance, to perform the con" densation without injection. He had a predilection for the " wheel engine, and much time and labour were spent on it, " while he was uncertain whether he should bring this, or the " reciprocating engine, first to the market. He had expe" rience to acquire in great works, and in the practice of " several trades employed in such constructions. He had " workmen to instruct, and to form; and to keep with him, " after they had acquired from him a little knowledge, and " were worth bribing away from him. But the chief cause of " the delay was that indelible trait in Mr. Watt's character, " that every new thing that came into his hands became a " subject of serious and systematic study, and terminated in " some branch of science. How rarely do we meet with such " a conjunction of science and art,—how precious when it is " found;—how much then does it deserve to be cherished! " What advantages have been derived within these twenty " years from this fortunate union;—how much then does it

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* Appendix to 'Mechanical Inventions of Watt,' No. VI. p. 229.

" become our courts to encourage and support it against the " unprincipled attacks of ignorant and greedy plagiarists, " who would deceive our men of property, ruin them by " expensive projects which terminate in disappointment, and " thus discourage those who alone can by their capital give " any effectual aid to the energy and genius of this country! " We boast of our Newton, and place him at the head of our " philosophers;—our Boulton and Watt want only *justice*, " and all Europe will place them at the head of our artists."

The originality of the invention, and its great importance to the public, were at once established by the plaintiffs; and, indeed, were admitted by the defendants. The very multitude of the infringers bore testimony to the value of the discovery; their occasional construction of tolerable engines on the new principle, proved the sufficiency of the specification; and their audacity was in proportion to the despair they felt of being able to rival, by honest means, the success of the inventor. The whole weight of the evidence was justly held to be in favour of the plaintiffs, on whose side were called men of the highest order of intelligence and of the greatest celebrity in physical science, as well as in the various departments of the arts:—such as De Luc, Herschel, Ramsden, Robison, Cumming, Southern, and others, most of whom, as has already been mentioned, had also given evidence in the previous case against Bull.

Among the host of opponents who, having in the first place themselves infringed the patent, were *disinterestedly* desirous, *for the benefit of the public*, that its validity should be overthrown, one of the most forward, pertinacious, and loud, was Joseph Bramah. This person, very well known for his ingenuity in mechanical improvements in locks, his hydraulic press, and other useful contrivances, attended as a witness on behalf of the defendants in 1796; but having on that occasion been cut short, by the Judge, in an endeavour to lay before the Court what he calls " a few remarks,"—(they extend to ninety-one printed pages!),—he at last delivered them to the public in the form of a letter to the Chief Justice, remonstrating against the verdict which had been unhesitatingly found for the plaintiffs. In the outset of this epistle, Bramah states that he was, at the trial, "much incapacitated by those alkalescent and morbific exhalations, "ever a consequence of large and close assemblies;" and the abrupt judicial syncope of his intended evidence he attributes, (no doubt justly enough), to the attention of the Court having "become flaccid through fatigue." Proceeding in this strain, he begs leave "to recapitulate in a comprehensible form the matter of that evidence, compounded," (he says), "with the whole substance which had occurred to his "understanding!"

The specification of the separate condenser generally, is, this excelling sage informs us, a "very abstruse and ambiguous concern:" and that of the steam-wheel, "a complete "jumble of incoherent, unconnected, absurd, and indigested "ideas; so blended *and coagulated with mystery*, ambiguity, "and impossibility in practice, that it is a disgrace to the "writer, and would undoubtedly *ruin any mechanic who might "attempt to analyse it.*"

The principle of working engines by the alternate expansion and contraction of steam, (the expansive principle added to the separate condensation), he introduces thus:—"And "behold! what does he," [Mr. Watt] "(by way of misleading), but propose what every man of chemical science must "reject, viz., to work engines by the partial expansion and "condensation of steam!"

Bramah offers it as "a condensation of his own ideas diffused through his letters," that "*all kinds of condensers*, "and even eduction-pipes, on the principle of Watt's engines, "*impede the working of the engine;*"—and "thinks that it "must be obvious to every one, *as it had ever been to him*, "*that Mr. Watt had really invented nothing but what would do* "*more mischief than good to the public.*"

The *learned* author of the pamphlet from which these quotations have been made, complains in it of having been called in Court, at the trial, "a fool, blockhead, shoemaker, and "water-closet-maker." If for the third of those epithets there were any foundation in fact, it would, indeed, rather appear that Mr. Bramah had too rashly disregarded the warning of the well-known Latin proverb, addressed to "criticising "cobblers." But the first and second terms of reproach we should be the last to apply to the author of so amusing a curiosity of literature as the pamphlet in question; furnishing as it does so sufficient a specimen of the spirit and style in which the rights of the claimants under the patent were resisted, as well as of the amount of erudition by which that resistance was audaciously supported. It was in the vexation caused by the multifarious piracies, of which Bramah's was one, that Mr. Watt was tempted, "in the anguish of his mind," almost to "curse his inventions;"—to declare that "there is nothing "more foolish than inventing;"—and that "nine-tenths of "mankind are knaves, and a large proportion of the remaining "one-tenth, fools." From an equally temporary cause alone, let us hope, also proceeded his evil opinion of some of the gentlemen belonging to a certain branch of the legal profession, whom he called "the anthropophagi of London;" and of whom he said, that "if all the counties in England would "join in petitioning Parliament to make it high treason for "any of the tribe to be found in the realm, it would be the "wisest thing they ever did!"* It was certainly unfortunate for the reputation of Bramah, himself a self-taught inventor of great mechanical ingenuity, that he should have been led, by whatever motive, into systematic and grudging opposition,—(which was also, happily, unsuccessful),—to the grand and prolific discoveries of Watt.

In our own day, this *doctrine of Bramah* appears in this country to have had one, and, so far as we know, but one follower. In a work on the steam-engine by Mr. Thomas Tredgold, printed in 1827, we find the following passage:— "The fortunate idea of condensing in a separate vessel, which "in Watt's engine is the only essential part in saving of fuel "beyond what Smeaton had accomplished, *would undoubtedly* "*in a short time have occurred to some other person;* and mines "must have been drained at a more economical rate, long

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* To Mr. Boulton, 12 April, 1780.

"before that monopoly ceased." This observation is accompanied by the further reflection, that "monopoly should never "be renewed, except so that any other person may, at a fair "and at a fixed rate of licence, join in it." Without too critically enquiring how far that can be called a *monopoly, in which any other person may join*,—whether, had Watt not lived, the celestial afflatus of invention "would undoubtedly" have descended upon, *e.g.*, Mr. Thomas Tredgold, or "some "other person,"—or whether, if the objection is intelligible at all, it does not apply to all grants of patents, quite as much as to any renewals of them,—we need merely remark that in the case of Boulton and Watt's extension of patent, "any other person" *was* allowed to exercise the invention at a fair rate of licence; which was usually, with great moderation, fixed at only one-third of the savings of fuel which the improved engine in each case effected. The only exceptions to that rule were in cases where the engine worked less than twelve hours a day, or where coals were cheaper than four shillings a ton.

The verdict of the jury, on occasion of both of the trials, having gone with the stream of testimony which flowed so overwhelmingly in favour of the patentees, the judgment of the Court finally established the legal validity of the letters patent, and effectually vindicated the justice of all the claims that Boulton and Watt had made. That decision has always been viewed as one of great importance to the law of patents in this kingdom, and was, of course, productive of momentous consequences in a pecuniary point of view to the patentees; as, besides heavy damages and costs being recovered from the actual defendants, the remainder of the horde of delinquents were thereby, at last, awed into subjection, and compelled to disgorge a large portion of their illegal gains. In judgment on the vanquished, however, mercy was not forgotten by the victors; and the terms of settlement insisted on were, it is believed, generally satisfactory to all parties. Mr. Watt used, long afterwards, to call the specifications his old *and well-tried* friends.

CHAPTER XXIV.

TERMINATION OF THE PATENT-PRIVILEGE OF 1769 AND 1775 — AND OF THE ORIGINAL PARTNERSHIP OF BOULTON AND WATT — CONTINUANCE AND INCREASE OF THEIR STEAM-ENGINE BUSINESS — ATTEMPTED ROBBERY — ASSISTANTS AT SOHO — WILLIAM MURDOCK, HIS LIFE, SERVICES, AND INVENTIONS — MR. WATT IN HIS OLD AGE — PNEUMATIC MEDICINES — FOUNDATION OF PRIZE IN GLASGOW COLLEGE — LIBRARY AT GREENOCK — CHARITABLE ACTS.

WITH the year 1800 came the expiration of the privilege of the patent of 1769, as extended by the statute of 1775; and also the dissolution of the original copartnership of Messrs. Boulton and Watt, of five-and-twenty years' duration; a term which had been fixed with a prospective reference to the duration of the privilege, and which, having at its commencement found the partners active and strong,

"In mezzo del cammin' di nostra vita,"

left them, at its close, far advanced on that toilsome journey, and disposed to resign the cares and fatigues of business to other and younger hands. Those two friendly associates, who might well be termed the fathers of the modern steam-engine, did not, therefore, in their own persons renew the contract which they had in earlier and more eventful times so strenuously, so successfully, and so happily fulfilled. But their respective shares in the concern were readily adopted, as the basis of a new contract, by their sons, Messrs. James Watt, jun., Matthew Robinson Boulton, and Gregory Watt; all distinguished by great talents, and already to a considerable extent initiated in the conduct of the business, by those valuable instructions which the experience of their fathers had so well enabled them to give; as well as by having held, from 1794, some individual interest in the property of the copartnership.

The new partners then entered on a course of enterprising management, from which one of their number, Gregory Watt, was too soon removed by his premature death in 1804. This lamented person, having never felt much interest in the dry details of business, had been by the kindness of his elder brother, James, in great measure relieved from them, and enabled to devote his mind solely to those higher pursuits of science and literature in which he found delight; retaining at the same time the independent circumstances and command of leisure which his share of the profits from the steam-engine manufactory enabled him to enjoy. In the case of the other two gentlemen, the business connection endured without any material alteration for a period of no fewer than forty years. And it is a remarkable fact, demonstrative alike of the continual advance in the development of the various resources of this country, and of the energetic ability with which the affairs of the Soho manufactory were conducted, that notwithstanding the cessation of the exclusive privilege, and the immense competition in the construction of steam-engines which speedily followed, so far was the business of Boulton and Watt from diminishing, that it continually increased, and became greatly more profitable than it ever had been in the days of its original founders. Even after all of his manifold improvements had been secured by patent, and were in course of execution in the various engines turned out from the Soho manufactory, Mr. Watt had made a very moderate estimate of the remunerative nature of the business;—for although in the summer of 1782 he mentioned that the clear income realised by it was 3000*l.* per annum, and might be 5000*l.*, he at the same time added that it might be less, or nothing; depending on how far Mr. Boulton and he might be able to defeat their opponents. “From the many opponents we are like to have,” he also wrote to Mr. Boulton,* “I fear that the engine business “cannot be a permanent one; and I am sure it will not in “any case prove so lucrative as you have flattered yourself:”

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* 20th February, 1782.

—and " I will stick by the engine business while it sticks to " me ; but we have got so many pretenders now, that I fear " they will make us little people. If so, let them."* " I do " not think that we are safe a day to an end in this enter- " prising age. One's thoughts seem to be stolen before one " speaks them. It looks as if Nature had taken an aversion " to monopolies, and put the same thing into several people's " heads at once, to prevent them ; and I begin to fear,"—he very unreasonably went on to say,—" that she has given over " inspiring me, as it is with the utmost difficulty I can hatch " anything new." †

But, towards the close of the last century, and on the favourable termination of the long law-suits, the business became so profitable as fully to satisfy the moderate desires of Mr. Watt; to provide an obvious source of independent income for his sons; and thus to remove the fears which had often pressed heavily on his mind, that he might possibly outlive its success.

At the very beginning of the century, viz. on Christmas eve, 1800, a great robbery was attempted at Mr. Boulton's silver-plate manufactory; a building which adjoined the engine-yards and workshops, and was at no great distance from his mansion-house. The following account of this affair appeared in the Birmingham newspapers at the time:—" On " Tuesday night last, a most daring robbery was attempted to " be perpetrated at Soho, by a gang of five men, which they " endeavoured to effect by bribing the watchman, who dis- " covered their intentions to Mr. Boulton; in consequence of " which, Messrs. Boulton and Co. procured the constables " from this town, and other assistants, to the number of " twenty in the whole, who were well armed, and concealed " in the manufactory. At the appointed hour the gang broke " into the premises, took 150 guineas, and loaded themselves " with a variety of silver articles. As soon as they attempted " to depart, the parties in ambush rushed upon them, and a " terrible conflict ensued; fire-arms were discharged on each

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* 22nd May, 1782.

† To Mr. Boulton, 14 February, 1782.

" side ; and, after a severe struggle, four of the five offenders " were secured. The fifth, though severely wounded, made " his escape from the premises, over the top of the building, " from which he fell, and got clear off. The course he took " has been discovered by his loss of blood, but he has not yet " been taken, though 50 guineas are offered for his apprehension. Four of the prisoners," [the whole number taken], " are wounded, and Mr. Boulton's watchman was shot in the " neck, but he is in a fair way of recovery. The four prisoners " were examined on Wednesday evening, and committed to " Stafford gaol."

The robbery need scarcely have been mentioned here, but for the accidental circumstance of it having become known to Sir Walter Scott, and having furnished him with an incident of great pictorial effect in one of his most romantic scenes, that, viz., in 'Guy Mannering' between Meg Merrilies and Dirk Hatteraick in the cavern :—"During this dialogue, Meg " was heaping some flax loosely together. Before answering " to this question, she dropped a firebrand upon the flax, which " had been previously steeped in some spirituous liquor, for it " instantly caught fire, and rose in a vivid pyramid of the " most brilliant light up to the very top of the vault," &c.* Sir Walter's graphic description of the robbery is given in Allan Cunningham's Memoranda, published in Lockhart's 'Life of Scott.'† "I like Boulton," continued Sir Walter; "he is a brave man, and who can dislike the brave? He " showed this on a remarkable occasion. He had engaged to " coin for some foreign prince a large quantity of gold. This " was found out by some desperadoes, who resolved to rob the " premises, and, as a preliminary step, tried to bribe the porter. " The porter was an honest fellow,—he told Boulton that he was " offered a hundred pounds to be blind and deaf next night. " 'Take the money,' was the answer, 'and I shall protect the " 'place.' Midnight came,—the gates opened as if by magic, " —the interior doors, secured with patent locks, opened as of " their own accord,—and three men with dark lanterns en-

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* Vol. i. p. 655, Abbotsford Edition.

† Chap. liii.

" tered and went straight to the gold. Boulton had prepared " some flax steeped in turpentine,—he dropt fire upon it, a " sudden light filled all the place, and with his assistants " he rushed forward on the robbers;—the leader saw in a " moment he was betrayed, turned on the porter, and shooting him dead, burst through all obstruction, and with an " ingot of gold in his hand, scaled the wall and escaped." " 'That is quite a romance in robbing,' I said; and I had " nearly said more, for the cavern scene and death of Meg " Merrilies rose in my mind."

Sir Walter, although quite correct as to the main feature of the illumination of the scene of plunder and rescue, was slightly inaccurate in one particular; for the porter, or watchman, although shot in the neck, recovered, and lived long afterwards on a pension which was the reward of his fidelity to his employer. He was, however, removed from the neighbourhood of Birmingham, to be safe from the threatened resentment of other members of the same lawless gang which had been so largely decimated; and so strictly was his incognito obliged to be preserved, that we have heard that his place of concealment was not communicated even to his wife: —a strong measure of domestic economy to which he must of course have been a consenting party. For three nights previously, the robbers had tried keys and examined the premises, " which, by our wise law," says Mr. Watt, " is no " felony; and, had we apprehended them, they would soon " have been let loose upon the public, and we could not have " rested in safety. We were, therefore, obliged to let them " commit the robbery; and, on their coming out, fell upon " them with guns, pistols, bayonets, and cutlasses. * * Our " young men were commanders-in-chief, and laid their plans " very well; but one of our guards came not soon enough " to their station, by which the escape took place, though by " a way deemed impracticable." Four of the thieves were taken. The fifth member of the marauding party was, as we learn from the proclamation of reward issued at the time, as well as from another part of Mr. Watt's letter just quoted, surnamed the " Little Devil," and had come from Manchester expressly to join what we may call the shooting-party; he broke his arm, and was otherwise badly wounded and bleeding from his fall; but, although some slugs had passed through his hat, he was uninjured by shot. He was not apprehended for four or five months afterwards. All the five prisoners were tried at the next assizes at Stafford, and the four first secured were sentenced to death; "the Little "Devil" was sentenced to be transported for seven years, possibly from having borne no active part in the murderous affray, and also, perhaps, in consideration of the suffering he had already undergone. In regard to the others, a point of law, as to how far the plate manufactory, which was within Mr. Boulton's grounds at Soho, but of course apart from his residence, came within the definition of a dwelling-house, and consequently, how far the offence committed was or was not a burglary, was reserved for the opinion of all the Judges; and we rather believe that the capital sentence was ultimately not carried out on any of the culprits.

We need scarcely observe, that during the last half-century the Soho works have been one of the principal sources,—(for a great portion of the time, indeed, *the* principal source),—of that vast supply of steam-power which the inventions of Watt have enabled this and other countries to obtain. At the public meeting in London on the 18th of June, 1824, at which a monument to Mr. Watt in Westminster Abbey was voted, the amount of power which had been thus created at Soho was stated by the late Mr. Boulton to be, in round numbers, equivalent to that of one hundred thousand horses; and since that time, up to 1854, an addition of nearly two-thirds of that amount had been made; giving a total sum of power equivalent to that of about one hundred and seventy thousand horses. We subjoin a return of the particulars, prepared from the most authentic records; and as upwards of seven hundred men have been kept in full employment at the great establishment to which we refer, there seems no reason to apprehend any diminution in the future extent of its usefulness and prosperity.

" MEMORANDUM.—SOHO FOUNDRY, 16 *March*, 1854.

" The number and power of the engines made by Messrs. Boulton, Watt, " and Co., to the date January, 1824, were thus reckoned by the late Mr. " Boulton and Mr. Creighton, (one of his assistants at Soho):—

	Engines.	Nominal horse-power.		Power of living horses required to do the same work.
" 283	for pumping and blowing .	11,247	× 4 =	44,988
" 805	rotative	12,618	× 3 =	37,854
" 76	boat engines	2,080	× 3 =	6,240
" 1,164		25,945		89,082

" And between January, 1824, and January, 1854, the numbers are the " following:—

" 34	for pumping and blowing .	2,403	× 4 =	9,612
" 164	rotative	7,517	× 3 =	22,551
" 243	boat engines	15,358	× 3 =	46,074
" 441		25,278		78,237

" Giving the following total numbers:—

" 1,164	25,945	89,082
" 441	25,278	78,237
" 1,605	51,223	167,319

" The first engine seems to have been made for Bedworth in 1776."

For the information of those of our readers who are not familiar with the reason of the difference between the nominal horse-power, and what may be called the real or effective horse-power of an engine, it may be mentioned, that an engine of a given number of nominal horse-power can, during a certain time, as *e. g.* from one to six hours, do the same amount of work as could be done by a like number of horses in the same time. But it can do more than this; for a living horse can, on an average, work effectively, day after day, only for about six hours out of the twenty-four, whereas the steam-engine can work for all the twenty-four hours. In order to ascertain the number of living horses, and therefore the *real* horse-power that would be required to do the same amount of work that is done by an engine of a given number of *nominal* horse-power, the nominal horse-power must be multiplied by four.

This, accordingly, is done in calculations of the effective power of pumping and blowing engines, where the application of the steam-power is *direct*. But in rotative engines, whether on land or for boats, there is estimated to be a loss of power in the action by the crank, &c., as compared with the direct application in the other case, which is allowed for by multiplying the nominal power only by three.

For the same reason, doubtless, it is that the horse-power in pumping and blowing-engines has always been calculated with an effective pressure of 9⅓ lbs. on each square inch of the piston, while in rotative engines it is only taken at a reduced effective pressure of 7 lbs.; these numbers being to each other in the same proportion as four to three, or 3 : 4 : : 7 : 9⅓. We are informed, on excellent authority, that "this mode of calculation is that which was adopted by *the* "*original Watt*, and is still followed at the Soho works."

The continued success of the Soho steam-engine works, and the high character of all their manufactures, were unquestionably owing not only to the commanding talents of those who presided over them, but also to the abilities of various excellent assistants; such as were Southern, the two Creightons, P. Ewart, and Lawson, all of whom, in various responsible capacities, rendered energetic and valuable service.* But the foremost place in that honourable rank we must assign to William Murdock, for upwards of half a century Mr. Watt's most able, faithful, and esteemed assistant; who, both in his intellectual endowments, and in the manly independence of his mind, possessed no inconsiderable resemblance to his revered master and friend.

Born in 1754, at Bellow Mill near Old Cumnock in Ayrshire, Mr. Murdock early manifested the most decided predilection for mechanical pursuits; and after qualifying himself for their prosecution chiefly by his own unaided industry, he offered himself to Messrs. Boulton and Watt in 1776, or 1777, and was at once employed by them at Soho in superintending the construction and erection of their engines. He was soon sent into Cornwall as the agent of the firm, where, after vigorously contending with many difficulties, he ultimately succeeded in giving great satisfaction to the mining interest, as well as to his own masters; and he was afterwards employed for nearly twenty years at Soho foundry.

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* We may say the same of Messrs. Gilbert Hamilton and James Brown, to each of whom, in acknowledgment of their great and long-tried skill in conducting that extensive business, the late Mr. Watt, of Aston Hall, bequeathed a considerable share in the capital stock of the present copartnership of James Watt and Co. He no doubt felt satisfied that he could not take a more effectual method of insuring prosperity to the great manufacturing association, the interests of which he had so much at heart.

M. Charles Dupin, in an interesting account which he has published* of the great meeting in 1824, for the purpose of voting a monument to Watt in Westminster Abbey,—his presence at which he declares he will ever esteem as one of the most impressive and delightful recollections of his travels in Great Britain,—says:—"There was to be remarked among "the spectators a venerable old man, whose intrepid services "I could have wished had also been rewarded by some flattering marks of public gratitude. Mr. Murdock directed "the application of the new steam-engines, to drain the water "of the Cornish mines. In order to adapt that moving "power to exhausting-pumps, and to establish the system in "mines of extreme depth, inundated by appalling quantities "of water, great skill in practical mechanics was requisite. "Mr. Murdock showed that he was full of all the resources "of genius, and the wisdom of experience, so as to triumph "over every difficulty. Scarcely had those obstacles been "surmounted, than the proprietors of the mines sought to "deprive Messrs. Watt and Boulton of the benefit of the "agreement into which they had mutually entered. But the "incorruptible Murdock showed himself insensible to every "temptation; he long withstood all menaces, and retired "only when he saw the cupidity of the men whose frauds he "defeated, threatening to destroy him in the mines by throwing him down their pits." Of this last anecdote of M. Dupin we have heard, from the late Mr. Watt, another version which is somewhat different, and, for many reasons, more likely to be correct;—viz., that some of the "captains" of the Cornish mines, on occasion of a meeting of several of their number with Murdock on business connected with the engines, having attempted to *bully* him, he quietly locked the door of the room in which they were assembled, stripped, and, making a dexterous use of those arms with which Nature had supplied him, administered to more than one of their number a lesson of persuasive efficacy, such as they would never forget, and such as he was never called on to repeat. He was, in truth, of Herculean proportions, and in muscular power nearly unrivalled.

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* 'Discours et Leçons sur l'Industrie, le Commerce, la Marine, et 'sur les Sciences appliquées aux 'Arts,' tom. i. p. 202, 1825.

M. Dupin adds, that he could have wished to have seen Watt, who was so pre-eminent in the art of discovering and attracting to himself men endowed with rare talent, recompensing the skill, the energy, and the integrity of Mr. Murdock, by assuming him as a partner along with Mr. Boulton, in their grand and rich enterprise. But here also we have it in our power to dispel the anxiety which M. Dupin thus again,—perhaps somewhat needlessly,—felt it incumbent on him to manifest on behalf of Mr. Murdock. For although never formally assumed as a partner in the Soho concern, and, therefore, remaining always exempt from all chance of loss in case of that business at any time failing of success, he always received a liberal income from his employers; and from 1810 to 1830, he was placed *on the footing of a partner*, without having to advance a shilling of capital to the partnership funds, without the risk of incurring any liability, and with a fixed salary of 1000*l.* per annum, assigned to him in lieu of a share of the fluctuating profits. From 1830, he lived in peaceful retirement in the neighbourhood of those works to which his energies had been successfully devoted, until his death, which occurred in 1839. His remains are deposited in Handsworth church, near those of Mr. Boulton and Mr. Watt; where "a bust by Chantrey serves to perpetuate the remembrance of his manly and intelligent features," and of the mind of which they were a pleasing index. There is also a fine portrait of Mr. Murdock in the hall of the Royal Society of Edinburgh, of which he was a Fellow.

On the subject of the economical employment of gas-light from coal, his systematic experiments commenced in 1792. For his paper on that subject presented to the Royal Society in 1808, which was read by Sir Joseph Banks, and printed in the 'Philosophical Transactions' for that year, (pp. 124-132), he received the large Rumford gold medal; and he will ever be known as the true inventor of the beautiful system of lighting by gas. "The original inventor of this application of the " gases," says Mr. Watt in 1809, " is Mr. William Murdock, " a most ingenious man, now at Soho here, under whose di- " rections several very large manufactories have been lighted, " at Manchester and elsewhere, by Boulton, Watt, and Com- " pany. Mr. M.'s invention is of fifteen or twenty years' " standing. I saw it employed at Soho in the fireworks for " the celebration of the last peace." While Mr. Murdock's improvements on this subject were in progress, Mr. Watt happening to hear a lady express admiration of the introduction of water by pipes into all the dwelling-houses of a large city, remarked that he hoped it would not be long before she would see fire and light introduced in the same manner; a prediction which then sounded strange enough, and yet was literally fulfilled. But that is by no means the only useful discovery with which Mr. Murdock's name is associated. He secured by patent, in 1799, "certain new methods of con- " structing steam-engines;" and, in 1810, " an improved " method for boring pipes, cylinders, and circular disks, out of " solid blocks and slabs of stone of any kind or description." In 1809 he made known, (not securing it by a patent), a new method of refining porter, &c., without the aid of isinglass, then, as now, a most expensive material; and for this he received a substantial and handsome reward from the brewers of the metropolis. The working-model of the steam-carriage of 1784 * shows how aptly he carried out the designs contained in the specifications of Mr. Watt; and the oscillating cylinder † is only one of very numerous and

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[*] See the 'Mechanical Inventions 'of Watt,' vol. iii. plate XXIX.; and p. 450, *infrà*.

[†] Ibid. plate XXXIV.

valuable suggestions with which he enriched the Soho machinery.

Although the commencement of the new æra in the history of Soho found Mr. Watt already past what is commonly called the grand climacteric of man's life, he happily long lived to witness the continued stability and immense progressive increase of his business, in the hands of those dear to himself. His health had never, from his childhood, been robust; and it still was variable; but it had strengthened as his age advanced, and had never, perhaps, been worse than what one of his engineering friends called "a sort of counterpoise to "prosperity, success, or happiness,—or, to speak more in our "own way, a kind of fly-wheels to the machinery;" * the fatigue of those very exertions which his laborious life had rendered compulsory seeming to have fortified rather than to have enfeebled his frame. His spirits also became naturally more equable, as the principal causes of his anxiety and occasional depression were removed; and, while he was destined to be one of those "so strong that they come to "fourscore years," his strength even then, as it could scarcely be termed "labour," was certainly very far from "sorrow." The period, indeed, which commenced with the new century, and brought him a release from active business, was a serene and golden time; in which, peacefully reposing from the honourable toil of his earlier days, he found a calm and constant satisfaction in their retrospect; and those hours of happy leisure were no less delightful to himself than instructive to the "troops of friends" who, in common with all that can add dignity or cheerfulness to old age, were gathered around him.

A wide range of subjects of a scientific and useful nature continued to attract the notice of his inquiring mind. Among other pursuits, he had been induced, by the sorrow he experienced in losing his daughter, who died of consumption at an early age, "to step," as he expressed it, "over the bounds

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* Mr. Telford to Mr. Watt, 17 December, 1801.

"of his profession," and to communicate to Dr. Beddoes the ideas he entertained on the employment of "pneumatic "medicines." It appeared to him that if poisons could be carried into the system of the lungs, remedies might be thrown in by the same channel; and that, although there seemed to be objections to the introduction, in that way, of powders, such as of Peruvian bark, &c., however finely they might be *mechanically* divided, yet that if the virtues of such substances could be obtained by solution or suspension in air of some species, they might have their full effect when inhaled and respired. With the view of aiding medical practitioners, as well as private patients, in their experiments and researches on this subject, he contrived a convenient apparatus for the preparation and inhalation of the various airs, which was extensively manufactured for sale at Soho. He also in many ways greatly aided Dr. Beddoes in his establishment of the Pneumatic Institution at Clifton, near Bristol: an establishment famous for having early profited by the services, and developed the chemical talents, of Humphry Davy. The system from which Beddoes hoped so much, although it has never yet realised his large expectations, seemed at first to produce some remarkable results; and it is impossible to despise the importance of facts, or to overlook the ingenuity of deductions which were contributed by men such as Beddoes, Jenner, Edgeworth, Humphry Davy, and Watt, and which led all of them to expect effects of an extensively sanative and beneficial character.*

It was always a favourite wish of Mr. Watt's heart to promote the attainment by others of that spirit of industrious research and invention by which he had himself been so entirely governed; and the following is a letter by which he founded, in 1808, a prize in Glasgow College, as some acknowledgment on his part of "the many favours" that learned body had conferred upon him, and of his sense of the importance of promoting the special study of the sciences of natural philosophy and chemistry. It is addressed to the Rev. Dr. William Taylor, the Principal.

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* See the 'Considerations on the 'Use of Factitious Airs, and on the 'Manner of obtaining them in large 'Quantities,' &c., by Dr. Beddoes and Mr. Watt, published at Bristol in 1794, 1795, and 1796.

" Heathfield, Birmingham, June 3rd, 1808.

" REVEREND SIR,—I take the liberty of requesting you, in " your official capacity, to communicate the following propo- " sition to the Faculty of your University, and, on my part, " to request their favourable acceptance of it.

" Entertaining a due sense of the many favours conferred " upon me by the University of Glasgow, I wish to leave " them some memorial of my gratitude, and, at the same " time, to excite a spirit of inquiry and exertion among the " students of Natural Philosophy and Chemistry attending " the College; which appears to me the more useful, as the " very existence of Britain, as a nation, seems to me, in great " measure, to depend upon her exertions in science and in " the arts. I therefore propose to settle 300*l.* upon the Col- " lege, in Trust, to be laid out at the best interest, upon " landed security, 10*l.* of which to be given annually as a " premium for the best essay on some subject in one of the " branches of Natural Philosophy hereinafter mentioned, " which shall be appointed by a majority of the Principal, " Professors, and Lecturers of the University, and which " shall be composed by any *actual* student of the University " who shall have gone through a regular course of Languages " and Philosophy, either at Glasgow or in any other Scottish " University. The prize to be adjudged by the majority " above mentioned, in conjunction with Gilbert Hamilton, " Esq., my brother-in-law, so long as he shall live; and [it] " shall be subjected to the same rules and regulations, as to " the time and manner of giving it in, as the other prize- " essays appointed by the University. If in any year no " essay shall be judged worthy of the prize, the same subject " shall be re-appointed for the following year, and the pre- " mium reserved for it to be adjudged at the same time with " the premium for such other subject as shall be regularly " appointed for such year; and if then no adequate essay " shall appear, the said premium to be added to the prin- " cipal sum.

"I know not whether the interest will be subject to the "property-tax; but, in any case, the surplus, whatever it "may be, after paying the premiums, and 10*s.* 6*d.* to the "clerk of the meeting, is to be added to the principal "annuity; until it shall accumulate so that the interest shall "be able to afford two premiums on two subjects, to be "appointed as aforesaid.

"I had at first intended that the subjects for the prize-"essay should be taken from any branch of Natural Philo-"sophy or Chemistry; and now think it proper to restrict "them to the following branches, and in the following "rotation:—

"First Year, to any branch of Mechanics, or its dependent "Arts.

"Second Year, to Statics, and the Machines and Arts "dependent.

"Third Year, to Pneumatics, Statical or Chemical Ma-"chines and Arts.

"Fourth Year, to Hydraulics, Hydrostatics, their Machines "and Arts.

"Fifth Year, to Chemistry, its Arts and Apparatus.

"The Sixth Year, the rotation to begin with Mechanics, as "before, and so on by five years' rotations.

"I should request a copy of the successful essay to be sent "me annually, and, after my decease, to my male representa-"tive; and I request that no public mention may be made "of this donation, by paragraphs in the newspapers, or other-"wise, until a prize come to be adjudged; [I] not being, as "far as I know, actuated by vanity, but by a desire to stimu-"late others to do as I have done.

"I reserve to myself, at any time during my life, by any "writing under my hand, to change either the rotation or the "subjects of the essays, as well as the other regulations con-"cerning them.

"Should what I now propose meet the approbation of the "Faculty, I shall immediately direct a proper deed to be "drawn, and the money to be paid to their order.

"Requesting you, Sir, to accept my most respectful com-

"pliments, and to present them to all the other members of "the Faculty, I have the honour to remain, Reverend Sir, "your most obliged, and most obedient humble servant, "JAMES WATT."*

Some years later, also, (in 1816), he made a donation to the town of Greenock, for the purpose of purchasing scientific books for the use of the mathematical school of the place, under the care and guardianship of the magistrates and town-council: his intention being "to form the beginning of a scientific library for the instruction of the youth of Greenock, "in the hope of prompting others to add to it, and of rendering his townsmen as eminent for their knowledge as "they are for their spirit of enterprise." This design, carried out (as he wished) by his townsmen, with the munificent aid of his son, the late Mr. James Watt, has been at last completed; and a large and handsome building, containing the library and a beautiful memorial statue of its founder, by Chantrey, is now a principal ornament of that busy and prosperous seaport, which boasts that James Watt was born in her.

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* This letter has been already printed in a volume prepared for private circulation, entitled 'Deeds 'instituting Bursaries, Scholarships, 'and other Foundations, in the College and University of Glasgow,' 4to., 1850, pp. 216-218. It is there stated, that "the Faculty having "gratefully accepted this donation, "on the terms proposed by Dr. Watt "himself, no further Deed of Foundation seems to have been considered "requisite."

We have, however, ascertained, on examining Mr. Watt's correspondence, that, on the 1st of July, 1808, he enclosed to Mr. G. Hamilton, to be put into proper form by Mr. Reddie, one of the town-clerks of Glasgow, the draft of a contract, in which the principles set forth in his letter of 3rd June to the Principal of the College were carried out on the one part, and on the other part the Principal and Professors of the said College bound themselves to perform all the conditions of the contract, under penalty of forfeiture of the said sum of 300*l.*, with all accumulations of interest. On the 14th of July, Mr. Reddie had received the draft, and promised to do what was required as speedily as he could. On the 15th of August, Mr. Watt sends to Mr. Hamilton the 'Deed of Gift,' which he had executed, desiring that Mr. Reddie might get a proper receipt written on it, and direct who should sign it (on the part of the College): "and when signed," adds Mr. W. "you will please to get it registered." On the 23rd October he writes to Mr. H.—"I am glad that the business "with the College is at last settled. "* * * When you are more re-"covered I shall be glad to have an "extract of the deed from the Town "books." And on the 11th Nov. he thanks Mr. Hamilton for his attention "in procuring" the extract of the trust-deed to the College.

This was not very many days before the death of Mr. Hamilton, "than whom," writes Mr. Watt, on the 4th Dec., "I never knew a more "friendly or worthy man, nor one "more useful to society;" and on the 24th of the same month he writes to his cousin, Mr. Robert Muirhead, "I had named Mr. Hamilton as one "of the judges, in deciding the "merits of the prize-essays to be "given [in] in consequence of my "donation to the College; but he "having vacated the place unfortunately, I shall appoint you, if you "please to do me the honour of accepting it."

Nor, amid such donations, given as aids to the promotion of sound and useful learning, were others wanting on his part, such as true religion prescribes, to console the poor and relieve the suffering. But those his benefactions, which were also secret, being usually accompanied at the time by an injunction not to make known the name of the donor, we shall not here seek farther to disclose; preferring to dwell on the comfortable truth, that "there be some persons that will "not receive a reward for that for which God accounts Him-"self a debtor: persons that dare trust God with their charity, "and without a witness."*

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* Izaak Walton, 'Life of Dr. John Donne,' p. 54, ed. Oxford, 1824.

CHAPTER XXV.

STEAM-NAVIGATION — ITS ORIGIN AND PROGRESS — PADDLE-WHEELS — EARLY STEAM-BOATS — PAPIN, HULLS, MILLER, SYMINGTON, FULTON, HENRY BELL, ETC. — MR. JAMES WATT, JUNIOR — HIS VOYAGE IN THE "CALEDONIA," IN 1817, TO GERMANY, BELGIUM, AND HOLLAND — H.M.S. THE "JAMES WATT" — NAVAL REVIEW IN 1856 — LOCOMOTIVE STEAM-CARRIAGES — MR. WATT'S PATENT, AND MR. MURDOCK'S MODEL, OF 1784 — MR. WATT'S VIEWS OF LOCOMOTION ON LAND BY STEAM — EDGEWORTH'S SUGGESTION OF A RAILROAD — LATIN EPIGRAM.

A SUBJECT which naturally excited a deep, and, indeed, at one time, rather an anxious interest in the breast of the great engineer, when resting in his latter days from the severer labours of his life,—

> " A guisa di leon quando si posa,"

was that of steam-navigation. With every confidence in the probable success of such a system, he seems never in any very especial manner to have directed the force of his own mind to the details requisite for carrying it out; a circumstance which is quite explained by the constant demands on his time and attention made by other branches of the steam-engine business, so long as he continued to be actively engaged in its prosecution. But, in times widely different from those in which he had asked his memorable question as to whether "a spiral oar" or "two wheels" were to be preferred for navigation by steam, he lived to know of the first complete and practically useful steam-boat being successfully employed in America; as well as of the British Channel being crossed, and the Rhine navigated by another; both vessels,—the American and the British,—having been impelled by engines manufactured at Soho, constructed on the principles invented by himself, and not without the benefit of his own direct inspection and counsels.

We have no intention of here entering at any considerable length on the history of steam-navigation,—a subject which has already been treated of by various competent authorities, and which perhaps offers materials for a still more comprehensive work than any that have yet appeared. But it may generally be remarked, that the introduction of that most valuable mode of conveyance and transport has been quite dependent upon, and nearly co-ordinate with, Mr. Watt's improvements on the steam-engine; that before those improvements were made known to the world, nothing of any importance in that way had been accomplished, and little even attempted or imagined; and that since the full development of those improvements, that perfection of power and safety with which the ocean is now traversed in every direction and to any distance, by vessels impelled by steam, has been rapidly and triumphantly attained. The steam-vessels of modern times may well remind us of the

> " Wondrous ships self-mov'd, instinct with mind," *

of Alcinous and his Phæacians. Nor is the

> " ——— *λαῖτμα τάχισθ' ἁλὸς ἐκπερόωσιν,*
> " *'Ηέρι καὶ νεφέλῃ κεκαλυμμέναι,*"—
>
> " Swiftly and secretly they cross the main,
> " In mist and cloud envelop'd,"—

of the original, less forcibly descriptive. We wish we could with equal verisimilitude continue the quotation:—

> " ——— *οὐδέ ποτέ σφιν*
> " *Οὔτε τι πημανθῆναι ἔπι δέος, οὐδ' ἀπολέσθαι* ! " †
>
> " ——— nor need they ever dread
> " Disaster or destruction ! "

To this end the ingenious industry of many successive engineers and mechanics has, it is true, eventually conduced: but the master-key which unlocked the *power* required for the performance of such a task, was the condensation of steam in a vessel separate from the cylinder, together with the means of converting the rectilineal motion of the piston-rod into a rotative one for paddle-wheels, or, as now practised, for a screw-propeller, or "spiral oar."

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* Pope's Homer's Odyssey, b. viii. l. 604.

† ΟΔΥΣΣ. Θ. 537-9.

We have already sufficiently exposed the fictitious letter in which Solomon De Caus is made to talk, in 1641, to an imaginary Marquis, of "navigating ships," as well as of moving carriages, and of working other miracles by means of steam. But the mere use of paddle-wheels, "remi rotatiles," or "rames "tournantes," moved by animal force, for the progression of boats, appears to have been of considerable antiquity. Not to carry our inquiries further back, they have been fully described by Valturius, in his great work on the 'Science of War,' in 1472; by William Bourne, in 1578; by Denis Papin, (as having been seen by him in use in England, probably in 1682), in 1690; by Savery, in 1698; by Du Quet, in 1702 and 1735; by the Comte de Saxe, in 1732, &c. Papin, also, in 1690, unquestionably suggested the employment of *the atmosphere* as a power, with a vacuum formed by the condensation of steam beneath a piston in a cylinder, the power being communicated by toothed and paddle-wheels "ad naves adverso "vento provehendas:"* and he represented the greatest probable obstacle to the construction of such a machine to be the difficulty of getting cylinders, of adequate size, sufficiently well made for the purpose they were intended to serve. Of the mere ingenuity of his suggestion, so far as it went, there cannot, of course, be a doubt; but this, like some others of his mechanical ideas, he seems not to have seriously attempted to reduce to practice, and, if he had done so, he would have found how entirely insufficient was the apparatus he proposed, now dignified by some writers with the name of his steam-engine, to produce such effects as he desired. The mechanical difficulty, also, which he has specified, although unquestionably very considerable, was only one of many, not less formidable, which Mr. Watt's more comprehensive view foresaw; and which it needed all the most constant and anxious exertions of his more powerful practical genius to encounter and overcome. Since the days of Papin, indeed, the experience of a century and a half has fully enabled us to judge how great was the distance between the imperfect conception of a project, such as he suggested in the passage quoted above, and its successful consummation.

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* See p. 145, *suprà*.

It still, curiously enough, remains uncertain whether Jonathan Hulls carried into effect the more elaborate invention for which he obtained a patent in 1736, and which he set forth in his celebrated pamphlet entitled 'A Description and 'Draught of a new-invented Machine for carrying Vessels or 'Ships out of or into any Harbour, Port, or River, against 'Wind and Tide, or in a Calm:' London, 1737. But he has, at least, minutely described the introduction of a Newcomen's engine into a large boat or barge to be employed as a tug, and has delineated such a vessel, fitted with fan (or paddle) wheels, towing a ship of war of upwards of thirty guns. His work, which seems to have been long overlooked, is now not common, and it is still more rare to meet with a copy containing the curious and highly illustrative engraving which forms its frontispiece; but it affords the strongest evidence which we possess, of a marine atmospheric steam-engine, working by paddle-wheels, having been constructed,—or, at all events, fully devised and figured in action,—so early as the period in question.

After the date of Mr. Watt's patent of 1769, (the great pivot on which all real advancement in the steam-machinery of modern times has turned), it is said that, in the United States, Mr. Ellicot, in 1775, and T. Paine, (less favourably known by his writings), in 1778, suggested the use of steam for propelling boats; as the Abbé Arnal did in France in 1781, for inland navigation; while in 1782 the Marquis Jouffroy built a steam-boat, which was tried on the Saône, but did not succeed. In 1783, Mr. James Rumsey of Virginia and Mr. John Fitch of Philadelphia both proposed methods of propelling boats, the one by a current of water forced out at the stern, and the other by paddles, but not in the form of wheels. It is said that Mr. Fitch constructed a steam-boat which was navigated between Bordentown and Philadelphia, but was soon laid aside.

In 1787, Mr. Miller of Dalswinton published a description, with engravings, of a triple vessel, propelled by paddle-wheels, turned by means of cranks, intended to be worked by men; adding, "I have also reason to believe that the power of the " steam-engine may be applied to work the wheels, so as to " give them a quicker motion, and, consequently, to increase " that of the ship." In 1788, Mr. Miller employed Mr. William Symington, of Wanlockhead, in Dumfries-shire, along with Mr. James Taylor, to superintend the construction of a small steam-engine in a pleasure-boat on Dalswinton Loch. This succeeding well, induced him to employ Mr. Symington to construct a larger steam-engine at Carron, for one of Mr. Miller's boats on the Forth and Clyde Canal, which was tried in 1789, and a speed of about seven miles an hour attained; but from other objections, (chiefly to the want of solidity in the machinery), from Mr. Miller's want of confidence in its ultimate success, and his attention being diverted to other pursuits, the boat was soon afterwards dismantled, and the engine removed from it. It has been lately stated that about the year 1787 Messrs. Furnau and Ashton made experiments in steam-navigation on the river at Hull, which ended in their building a boat which for some time plied between Beverley and Hull, and another of a larger size, which was bought by the Prince of Wales, afterwards George IV., and fitted up as a pleasure yacht. The latter vessel is said to have been burned: what became of the former is not stated.

From January, 1801, till April, 1803, Mr. Symington was employed by Lord Dundas to make a series of experiments on steam-boats, with the view of their being used on the Forth and Clyde Canal; and the towing-vessel, the "Charlotte " Dundas," which he then constructed, appears to have been entirely successful, in so far as regarded moderate power and speed. The use of this vessel, however, on the canal was discontinued in consequence of the injury which it was apprehended the washing of the waves in its wake might do to the banks; and although the Duke of Bridgewater was so satisfied of the advantages of the invention as to have given Mr. Symington an order to build eight similar boats, to be used on his canal, yet the hopes of the enterprising inventor were destined to be crushed just at the very "moment of projec-"tion;" for "the same day that he was informed by Lord "Dundas of the final determination of the Committee not to "allow steam-boats to be employed on the canal, he received "intelligence of the death of the Duke of Bridgewater."*

In 1801, Symington's steam-boat was visited, minutely inspected, and tried, by Robert Fulton, a native of Pennsylvania, (the son of an emigrant from Dumfries-shire); who, as an engineer,—not merely an amateur,—devoted much time and attention to the subject of steam-navigation. And early in 1802, he being then resident in Paris, and in full communication with Mr. Livingstone, the envoy from the United States to France, who appears to have been attached to similar pursuits, he addressed a letter to Mr. James Watt, jun., in which he inquired the price and other particulars of a small engine of five horse-power. In a letter written a week later, he made inquiries as to the employment of high degrees of heat in small engines, and the limit to which it might be carried, in order to render them light and compact,—for this, with his views, was necessarily a cardinal point,—and then he went on to say, "The object of my investigation is to find "whether it is possible to apply the engine to working boats "up our long rivers in America. The persons who have "made such attempts have commenced by what they called "improving Watt's engine, but without having an idea of the "physics which lay hid in it from common observers; but "such improvements have appeared to me like the improve-"ments of the preceptor of Alcibiades, who corrected Homer "for the use of his scholars. Their ill success, and their "never having found a good mode of taking a purchase on "the water, are the reasons why they have all failed. "Having, during the course of my experiments on sub-"mersive navigation, found an excellent mode of taking a "purchase on the water, I wish to apply the engine to the "movement. The only thing which is wanting is to arrange

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* Woodcroft 'On Steam Navigation,' 1848, p. 55.

"the engine as light and compact as possible," &c. And, in the postscript of his letter, he proposes for Mr. Watt's consideration some schemes of engines suggested by Mr. Livingstone: schemes on which we do not find that any opinion was then expressed, but which appear not to have been very clearly explained, and which, in so far as their construction was intelligible, did not promise to be very effective.

On the 6th of August, 1803, Mr. Fulton ordered his first engine from Soho, repeating the application in person in 1804. The diameter of the cylinder was 24 inches, with a stroke of four feet, being about nineteen horse-power. "The principal "parts of the engine were made and forwarded early in 1805; "the planning and execution of the subordinate parts, as well "as of the connecting and paddle machinery, having been "undertaken by Mr. Fulton himself. He built a vessel from "his designs at New York, called the 'Clermont,'* and having "erected the machinery on board of her, the first trial was "made in the spring of 1807, and was eminently successful; "and this vessel was soon after established as a regular steam-"packet between New York and Albany."†

Within six years from the first trial-trip of the "Clermont," six steam-vessels had been built for Mr. Fulton, and were in constant and successful use in America for the conveyance of passengers.

"It is a Mr. Fulton," writes Mr. Watt to Dr. Townsend of Bath,‡ "who has constructed the steam-boats in America: "two of the engines have been made by Boulton, Watt, and "Company, but the machinery has been made entirely in "America, under his own direction. The following is his "account of his boat, (Sept. 15th, 1810):—'The first engine "'thus in use was 24-inch cylinder, 4-feet stroke, which drove "'a boat 166 feet long and 18 feet wide, drawing 2½ feet of "'water, at the rate of 5 miles an hour on the Hudson river; "'that is, taking the tide for and against the boat, the

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* From a residence of Mr. Livingstone's on the Hudson river, about two-thirds of the way from New York to Albany.

† The distance between New York and Albany has, we believe, been ascertained by a recent survey to be 125 geographical miles.

‡ April 13th, 1812.

" 'average velocity is 5 miles an hour.' The boats go regu-
" larly between New York and Albany, distant 160 miles,
" and he is forming similar establishments on other rivers,
" and has had a second engine of 28-inch cylinder, 4-feet
" stroke; and one of the latter size has been made to navi-
" gate a boat between Montreal and Quebec.

"I am informed by a friend who has seen the steam-boat,
" that the engine and boilers occupy about one-third of the
" length of the boat, and that the engine operates by com-
" municating motion to a water-wheel on each side of the
" boat, which he said were about 6 feet diameter, and 3 feet
" wide in the sole; but I think they must be of a larger
" diameter.

"You will readily see that a machine of this kind could
" not pass bridges and locks, which all our navigations are
" full of; but might navigate in the tide-way of the Thames
" or Severn, or other rivers clear of bridges, &c., and suffi-
" ciently wide.

"Peter Miller, Esq., of Dalswinton, in Scotland, tried many
" experiments, ten or more years ago, with a boat of this con-
" struction, and might have succeeded if he had had a better
" engineer. He is now a *very* old man. On the whole, as far
" as it is at present known to me, I think it would not answer
" the purpose you want. I believe Mr. Rennie is engineer to
" your canal: nobody is more able to advise you on this head."

In 1811, Mr. Henry Bell, a citizen of Glasgow, who, since 1800, had repeatedly urged the subject of steam-propulsion on the attention of the British government, and had also aided Fulton with drawings of machinery, &c., took the decided and enterprising step of himself trying in Scotland, at his own risk and under his sole direction, an experiment similar to that which had succeeded so well in America. He had a boat, called from the great heavenly body of that kind which made its appearance in that year, the "Comet," built at Port Glasgow, in the yard of Messrs. J. and C. Wood, which, propelled by a steam-engine of his own construction, was finished by the end of 1811. It plied on the Clyde, between Glasgow and Greenock, early in 1812; and thus became the forerunner of that system of practical steam-navigation which has since so widely extended itself in this country. The "Comet" was forty feet in length, of twenty-five tons measurement, and four horse-power; but other vessels soon followed of somewhat greater dimensions, fitted with engines of proportionally greater powers;—the largest, built in 1813, of which we are aware, being the "Glasgow," of 74 tons and 16 horse-power,—in 1814 the "Morning "Star," of 100 tons and 26 horse-power,—and in 1815, the "Caledonia," of 102 tons and 32 horse-power. In that year, two steam-vessels went from the Clyde to the Thames; one by the Forth and Clyde Canal to Leith, and thence by the east coast; and the other by the west coast and round the Land's End:—these being, so far as we know, the first attempts at steam-navigation made in the open sea of our coasts.

"During his last visit to Greenock in 1816," says Mr. Williamson, "Mr. Watt, in company with his friend Mr. Walkin-"shaw,—whom the author some years afterwards heard relate "the circumstance,—made a voyage in a steam-boat as far as "Rothsay and back to Greenock,—an excursion which, in "those days, occupied the greater portion of a whole day. "Mr. Watt entered into conversation with the engineer of "the boat, pointing out to him the method of 'backing' the "engine. With a foot-rule he demonstrated to him what was "meant. Not succeeding, however, he at last, under the "impulse of the ruling passion, threw off his overcoat, and, "putting his hand to the engine himself, showed the practical "application of his lecture. Previously to this, the 'back-"'stroke' of the steam-boat engine was either unknown or "not generally known. The practice was to stop the engine "entirely a considerable time before the vessel reached the "point of mooring, in order to allow for the gradual and "natural diminution of her speed."*

In April, 1817, Mr. James Watt, jun., having purchased the "Caledonia," which from defects in her engines had been little used since her launch in 1815, had her machinery taken out, and replaced by two new engines of Soho manufacture, of 14 horse-power each. In October of that year, he went over in her to Holland, and ascended the Rhine as far as Coblentz; having thus been the first to leave the British shores and cross the Channel by so novel, and, as it was then esteemed, so hazardous a mode of transit. But although

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* 'Memorials of Watt,' p. 234.

> "Illi robur et æs triplex
> "Circa pectus erat,"

even he could scarcely then foresee that in later days the imitation of his daring enterprise would be circumscribed only by those bounds by which the proud waves of the ocean are stayed.

The "Caledonia" having left Margate on the 14th of October, 1817, arrived off West Kapelle, Walcheren, in ten minutes more than twenty-four hours, and came to anchor in the Keeting near Vianen three hours later; having run, under steam, at an average speed of 7½ knots an hour. In her voyage from Rotterdam to Cologne, by Nimeguen, Emmerick, Wesel, and Düsseldorf, the time actually occupied under way, with a strong easterly wind and current against the vessel during the whole of it, and for nine hours only one engine at work, was 48 hours, 52 minutes. As she steadily forced her course against the impetuous waters of the Rhine, her track marked by—

> "Smoke in air and foam upon the wave,"*

she excited, as may well be imagined, the admiring wonder,—in some cases the wondering horror,—of the natives. She presented a strange contrast, such as has often since struck the eye of the traveller, to those most shapeless and primitive of all vessels, the huge rafts of timber from the Helvetian forest, which with whole families, with their flocks and herds, inhabiting them for weeks together, seem, as sluggishly they descend the stream, to be leviathan villages of diluvian date.

On her homeward voyage from Coblentz, the "Caledonia" entered the Scheldt, and visited Antwerp. She was then laid up for part of the winter in the harbour of Rotterdam, for repairs and alterations. After her return to the Thames in the spring of 1818, Mr. J. Watt, jun., made no fewer than thirty-one series of experiments with her on the river, (the whole number of those experiments amounting to two hundred and fifty);* which resulted in the adoption of many most material improvements in the construction and adaptation of marine engines, and in an immense, though gradual extension of that branch of the manufacture at Soho. From the particulars already given of the amount of steam-power produced at that establishment, it appears that the marine engines manufactured there, up to 1854, were in number 319; of 17,438 *nominal*, or 52,314 *real* horse-power.†

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* Cary's Dante; 'Hell,' canto xxiv. l. 50.

The memory of James Watt will now be worthily perpetuated in the British navy, by the fine screw steam man-of-war of that name, of 91 guns; which was launched at Pembroke dock-yard in 1853, and fitted with Soho engines.‡

But the greatest triumph of steam,—and, therefore, of the name of Watt,—that the world has ever witnessed, was beheld at the great Naval Review which took place at Spithead on the 23rd of April, 1856, at the close of the war with Russia; when a British fleet of no fewer than two hundred and forty sail, from the largest line-of-battle ship, such as the "Duke of Wellington" of 131 guns and 1100 men, down to floating mortar-batteries, and gun-boats carrying only 2 guns and 25 men, was assembled: and, of the whole number of that vast array, not more than ten ships were without steam-power. The day was so calm, that sails would have been comparatively of little use; and scarcely one was set during the whole time that the review lasted. The orderly and rapid movements and manœuvres of the different divisions of the immense fleet, extending, even when ranged in triple line, very many miles in length, were thus performed solely under the power of steam, the absence of sails leaving the rigging and spars standing in all their fairy-like lightness and grace. Almost all of the vessels also were propelled by the screw,—the "spiral oar" of Mr. Watt's letter of 1770,—instead of by paddle-wheels, so that the surface of the water seemed scarcely broken as they moved majestically along; and, by the use of a peculiar species of coal, (the Welsh anthracite), the nuisance of smoke from the engine-fires was entirely prevented. Thus,

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* From a memorandum made by one of the party present on the occasion, we find that on the 14th of July in that summer, the "Caledonia" steamed to the Nore and back—nearly 100 miles—in ten hours; to the great astonishment, among others, of a French gentleman on board, and the delight of Chantrey the sculptor, who was another member of that party of pleasure. We cannot resist the temptation of placing side by side with the creditable performance of the "Caledonia" of those early days, the still more dazzling speed of the voyages made, in later ones, by the beautiful "Persia," an iron steam-ship built by Robert Napier and Sons, in 1855; measuring 375 feet in length, 46 in breadth, and 3590 tons, with a power of 850 horses. The "Persia," propelled by paddles, made her "out" passage from Liverpool to New York, (adding difference of time), in 10 days, 1 hour, 1 minute; and her "home" passage on her return from New York to Liverpool, (deducting difference of time), in 9 days, 5 hours, 46 minutes.

† See p. 423, *suprà*.

‡ The engines in question, as we have been informed by one of their makers, were originally intended for the "Vulcan," to exert the power of 700 horses at 60 strokes per minute; in the "James Watt," owing to the employment of a larger size of screw-propeller, they are only to make 50 strokes per minute, and the estimate of their power will be reduced to that of 600 horses. In casting the fine brass screw-propeller for H.M.S. the "James Watt," *ten tons and a half* of metal were employed.

> "While not a breath disturb'd the deep serene,
> "And not a cloud o'ercast the solemn scene,"

the whole of the evolutions took place with a steadiness, a celerity, and an apparent ease and absence of effort, that were quite magical in their effect; forming a spectacle unrivalled in its kind, and that will never be effaced from the memory of those who were present at it.

With regard to another application of steam power, of kindred interest and importance, that, viz., to locomotion on land, it is remarkable enough that when Mr. Watt's attention was first directed, by his friend Robison, to the steam-engine, "he (R.) at that time threw out an idea of applying the "power to the moving of wheel-carriages." "But the "scheme," adds Mr. Watt, "was not matured, and was soon "abandoned on his going abroad." *

It may be here incidentally mentioned that the Abbé Huc, in giving an account of the character and career of Father Verbiest, a successful Jesuit missionary among the Chinese,

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* Robison, p. 113; and p. 75, *suprà*.

who died in 1688, says:—“ It is highly probable, that he “ anticipated the great discovery of modern times, the motive “ power of steam. In his learned work, entitled ‘Astronomia “ ‘ Europæa,’ there is a curious account of some experiments “ that he made at Pekin, with what we may call steam- “ engines. He placed an æolipile upon a car, and directed “ the steam generated within it upon a wheel to which four “ wings were attached; the motion thus produced was com- “ municated by gearing to the wheel of the car. The ma- “ chine continued to move with great velocity as long as the “ steam lasted; and, by means of a kind of helm, it could be “ turned in various directions. An experiment was made “ with the same instrument applied to a small ship, and with “ no less success; and Father Verbiest, after giving an account “ of these experiments, adds these very remarkable words:— “ ‘*Dato hoc principio motûs, multa alia excogitari facile est.*’ ” *

In August, 1768, Dr. Small informed Mr. Watt that “ Mr. “ Edgeworth, a gentleman of fortune, young and mechanical, “ and indefatigable,” had “ taken a resolution of moving land “ and water carriages by steam,” and had made considerable progress for the time he had employed himself in that line. “ He knows nothing,” added Dr. Small, “of your peculiar “ improvements, but seems to be in a fair way of knowing “ whatever can be known on such subjects.” † In allusion to the same subject, Dr. Small wrote to Mr. Watt a month later, “ Your very clever friend Mr. Robison and his pupil passed “ Friday evening with me to my great satisfaction. I told “ them I hoped soon to travel in a fiery chariot of your “ invention.” ‡ Seven months later, “ A linen-draper at “ London, one Moore, has taken out a patent for moving “ wheel-carriages by steam. This comes of thy delays. I “ dare say he has heard of your inventions. Do come to “ England with all possible speed. At this moment how I “ could scold you for negligence! However, if you will come “ hither soon, I will be very civil, and buy a steam-chaise of

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* Huc's ‘Christianity in China, Tartary, and Thibet,’ vol. iii. 1858.

† Dr. Small to Mr. Watt, 12th August, 1768.

‡ The same to the same, September, 1768.

" you, and not of Moore. And yet it vexes me abominably " to see a man of your superior genius neglect to avail him- " self properly of his great talents." * Mr. Watt, in writing to Dr. Roebuck of this, says, " This was a thing I hoped to " accomplish by the circular engine," † [or steam-wheel.] And he replies to Small :—" If linen-draper Moore does not use my " engine to drive his chaises, he can't drive them by steam. " If he does, I will stop them. I suppose, by the rapidity of his " progress and puffing, he is too volatile to be dangerous."— " You want a steam-chaise; pray make one. I give you leave, " and will also give you advice,—not gratis, however, but for " good deeds done and to be done."—" Of all things in life, " there is nothing more foolish than inventing. Here I work " five or more years contriving an engine, and Mr. Moore hears " of it, is more *éveillé*, gets three patents at once, publishes " himself in the newspapers, hires 2000 men, sets them to " work for the whole world in St. George's Fields, gets a fortune " at once, and prosecutes me for using my own invention ! " ‡

Moore's fortune, however, was not got at once by steam-carriages; nor, as may be supposed, did the imagined prosecution ever take place. " After much inquiry about Moore," says Dr. Small, " I can learn nothing satisfactory, only that " he is no profound philosopher, and so, in all probability, " unacquainted with the properties of substances of which " you have availed yourself. Perhaps he may pay you a " large sum of money for leave to use your inventions. If " so, ask 12,000*l.*, and not 1200*l.* He is rich and sanguine: " and indeed, if wheel-carriages and vessels can be moved " commodiously by steam, the invention is worth much more " money." § " I have thought," adds the Doctor, on the 5th November, " of a very easy method of constructing your " wheel, and of a most easy and obvious method of moving " carriages by a reciprocating engine, provided a tolerably " tight piston can be found. The weight of a machine for a

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[*] Dr. Small to Mr. Watt, 18th April, 1769.

[†] Mr. Watt to Dr. Roebuck, 28th April, 1769.

[‡] Mr. Watt to Dr. Small, 28th April, 1769.

[§] Dr. Small to Mr. Watt, 10th May, 1769.

" post-chaise will not be more than 300 lbs., water and all, " and it will be contained in very small compass."

In the seventh " new improvement," however, set forth in the specification of his patent of 1784, Mr. Watt described the principles and construction of " steam-engines which are " applied to give motion to wheel-carriages for removing " persons or goods, or other matters, from place to place, in " which cases," he says, " the engines themselves must be " portable. Therefore, for the sake of lightness, I make the " outside of the boiler of wood, or of thin metal, strongly " secured by hoops, or otherwise, to prevent it from bursting " by the strength of the steam; and the fire is contained in a " vessel of metal within the boiler, and surrounded entirely " by the water to be heated, except at the apertures destined " to admit air to the fire, to put in the fuel, and to let out " the smoke; which latter two apertures may either be situated opposite to one another in the sides of the boiler, or " otherwise, as is found convenient; and the aperture to " admit air to the fire may be under the boiler. The form " of the boiler is not very essential, but a cylindric or globular " form is best calculated to give strength. I use cylindrical " steam-vessels with pistons, as usual in other steam-engines, " and I employ the elastic force of steam to give motion to " these pistons, and after it has performed its office I discharge " it into the atmosphere by a proper regulating valve, or I " discharge it into a condensing vessel made air-tight and " formed of thin plates or pipes of metal, having their outsides exposed to the wind, or to an artificial current of air " produced by a pair of bellows, or by some similar machine " wrought by the engine or by the motion of the carriage; " which vessel, by cooling and condensing part of the steam, " does partly exhaust the steam-vessel, and thereby adds to " the power of the engine, and also serves to save part of the " water of which the steam was composed, and which would " otherwise be lost. In some cases I apply to this use " engines with two cylinders which act alternately; and in " other cases I apply those engines of my invention which " act forcibly both in the ascent and descent of their pistons,

" and by means of the rotative motion in figure 20th,* or of " any other proper rotative motion, I communicate the power " of these engines to the axis or axle-tree of one or more of " the wheels of the carriage, or to another axis connected " with the axle-tree of the carriage by means of toothed " wheels; and in order to give more power to the engine " when bad roads or steep ascents require it, I fix upon the " axle-tree of the carriage two or more toothed wheels of " different diameters, which when at liberty can turn round " freely on the said axle-tree when it is at rest, or remain " without turning when it is in motion; but, by means of " catches, one of these wheels at a time can be so fixed to the " axle-tree, that the axle-tree must obey the motion of the " toothed wheel, which is so locked to it. And upon the " primary axis, which is immediately moved by the engine, " or which communicates the motion of the engine to the " axle-tree of the carriage, I fix two or more toothed wheels " of greater or lesser diameters than those on the axle-tree, " which are moved by them respectively, so that the wheels " on these two axles having their teeth always engaged in " one another, the wheels on the axle of the carriage always " move with the wheels on the axle of the rotative motion, " but have no action to turn the wheels of the carriage except one of them be locked fast to its axle-tree,—then the " latter receives a motion faster or slower than that of the " axle of the rotative machinery, according to the respective " diameter of the wheels which act upon one another. In " other cases, instead of the circulating rotative machinery, " I employ toothed racks or sectors of circles worked with " reciprocating motions by the engines, and acting upon " ratchet wheels fixed on the axles of the carriage. And I " steer the carriage, or direct its motion, by altering the angle " of inclination of its fore and hind wheels to one another by " means of a lever or other machine. As carriages are of " many sizes and variously loaded, the engines must be made " powerful in proportion. But to drive a carriage containing

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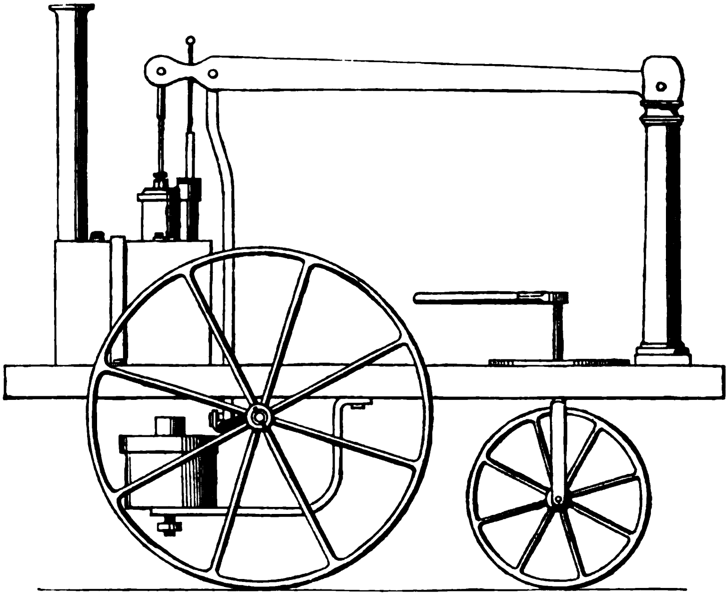
* A sun-and-planet wheel.

" two persons, will require an engine with a cylinder seven " inches in diameter, making sixty strokes per minute of one " foot long each, and so constructed as to act both in the " ascent and descent of the piston; and the elastic force of " the steam in the boiler must occasionally be equal to the " supporting a pillar of mercury thirty inches high."



Working Model of a Locomotive Engine made by Mr. W. Murdock in 1784.

Also in 1784, Mr. Murdock made a working model of a locomotive engine upon the principles so specified by Mr. Watt, which performed well, and is still in existence. With a spirit-lamp for a furnace, its cylinder attached to the boiler, and its piston-rod working a beam that turned the driving-wheels by a crank, it was placed in the Great Exhibition of 1851,* where it attracted much notice. It stood among the " machinery at rest," on the colossal marine engines of 700 horse-power, manufactured by Messrs. James Watt and Co., which have since been erected in the fine 91-gun screw steam-ship the "James Watt;" and by the side of that interesting little model was placed another, also of diminutive size, of a steam-engine with *an oscillating cylinder*, invented and constructed by Mr. Murdock in the year 1785. The model of the locomotive engine is now in the possession of Messrs. James Watt and Co.; that of the oscillating cylinder remains, a valued heirloom, in the family of Mr. Murdock.*

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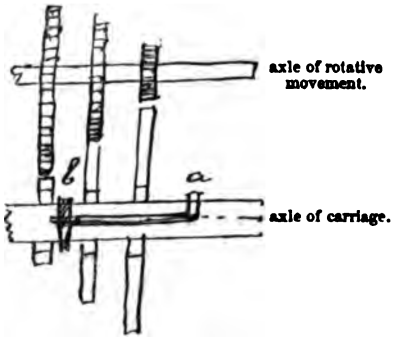
* See the 'Official Catalogue,' vol. i. p. 211.



In reference to this specification, Mr. Watt writes to Mr. Boulton,† "I have given such description of engines for wheel-" carriages as I could do in the time and space I could allow " myself; but it is very defective, and can only serve to keep " other people from similar patents." And, ten days later,‡ " I wrote to you last night, and now sit down to give you some " of my ideas on the wheel-carriage scheme, and have there-" fore annexed that article of the specification, by which you " will see the general idea. The engine may either be con-" nected with the rotative motion by a working-beam, or may " be placed directly over the secondary axle, and work the " rotative motion by means of two rods coming down on each " side of the cylinder from a cross-bar on the top of the " piston-rod, guided perpendicularly by a sliding frame; but " I am inclined to prefer a " working-beam, which in " this case may be short. " I do not know that the " organ-pipe condenser will " make much vacuum, but " it may, by the *help of* " *the bellows*, condense, and " save most of the water. " On the side you have a " sketch of the two axles, " and of the means I use to " lock and unlock the wheels which connect them together, " so as to make the carriage go faster or slower at pleasure,

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* Both of these curiosities of the engineering art were, by the permission of their respective proprietors, delineated and engraved for the 'Mechanical Inventions of Watt;' see vol. iii. plates XXIX. and XXXIV.

† 17th August, 1784.

‡ 27th August, 1784.

" or, at least, to have more or less power at will. The " piece (*a b*) slides in a hollow, and two slits in axle of " the carriage; when *b* is in the place drawn, the rotative " motion can turn without moving the carriage; but when " *b* is placed so as to be in a slit which is in one of the " wheels, then the wheel will cause the axle to turn round or " to break *b*; and *b* is always disengaged from one wheel " before it is locked to the other. As to the size of the " cylinder, boiler, &c., I calculate that, suppose the power " necessary to move a post-chaise on a plain to be 80 lbs. " weight, and the chaise to move at the rate of 4 miles per " hour, or 6 feet per second, let the moving-wheel be 4 feet " diameter, then it will make 1 revolution in 2 seconds, and " if the engine makes 60 strokes per minute, it will make one " revolution for 2 strokes; but as the rotative motion will " make 2 revolutions per stroke, it will make 4 revolutions " for each turn of the wheel of the carriage, and 80 lbs. × " 6 feet = 480 lbs. 1 foot high per second, and supposing the " stroke of the engine 1 foot long, 480 ÷ 2 must be its power " = 240 = 6 lbs. on inch to a 7-inch cylinder; but as going " up hills it will require a power of 400 lbs. to drag the " chaise up, the power in these cases must be increased 5 " times, that is, *the axle* of the carriage must make only 1 " turn for 20 turns of the rotative axle, and will then move " only 12 feet in 10 seconds; but this inconvenience may be " something lessened by letting the steam get stronger at " such times.

" A cylinder of 7 inches diameter and 12-inch stroke will " take something more than ½ a foot of steam per double-stroke, " supposing it to be working with a condenser; consequently " it would take 30 cubic feet of steam per minute = 1800 " feet of steam per hour, which, supposing it to be equal to " 1 cubic foot of water, would require a boiler of 8 feet sur- " face exposed to the fire to make any tolerable performance " in respect of fuel; but as we can *depend* on no aid from " condensation, we must suppose this steam to be at least " 1½ times as dense as the common steam, therefore there " must be a surface of 12 feet exposed to the fire, if not

“ more; let us leave the form of the boiler out of the case at
“ present. The surface of 12 square feet which we suppose
“ to be exposed to the fire, must be covered with a shell of
“ water of some thickness, which, upon the average, I shall
“ suppose to be 6 inches thick, which will make the whole
“ quantity of water necessary = 6 cubic feet, supposing no
“ magazine of water to be carried. As we must suppose the
“ copper of the boiler which is to stand such violent steam to
“ be at least $\frac{1}{4}$ inch thick, it will weigh at least 10 lbs. per
“ square foot; we have then 120 lbs. for the inside part of
“ the boiler; and as there must be steam-room, and the
“ outside case of the boiler must be 1 foot wider than the
“ inside, supposing the inside oblong 1 foot wide, 3 feet long,
“ and 18 inches high, then the outside must be 4 feet long,
“ 2 feet wide, and $2\frac{1}{2}$ feet deep, which would have 35 feet
“ surface, which at 10 lbs. would weigh 350 lbs. The boiler,
“ then, with the included water, would weigh 830 lbs., without
“ any allowance for a grate or wooden case; but, in relation
“ to the latter, the copper might be made so much thinner as
“ to allow for it, and perhaps some means may be hit upon to
“ make the boiler cylindrical, with a number of tubes passing
“ through, like the organ-pipe condenser, whereby it might be
“ thinner and lighter; but I fear this would be too subject to
“ accidents. Let us suppose, however, that it could be re-
“ duced to 300 lbs. weight, which, with the water, would
“ make 660 lbs.

	lbs.
“ A post-chaise weighs about	1000
“ The boiler and water would weigh . . .	660
“ The engine and wheels, say about . . .	200
“ The fly, 3 feet diameter, containing the power of “ one stroke of the engine	100
“ The organ-pipe condenser and bellows, say . .	100
“ Three persons, including the driver . . .	400
“ Their luggage	200
“ Coals for four hours, at 15 lbs. per hour . .	60
“ And if the organ-pipe condenser is not found suffi- “ cient to condense the steam, water must be “ carried, say for two hours	180
	2900

" And then, if the machinery cannot be made lighter than " has been stated, the power will, I am afraid, prove insufficient, and a further augmentation of the boiler, &c., must " take place. If there were no friction, the power of 80 lbs. " would be sufficient to draw the carriage up an ascent of 1 " in 36 on a hard smooth plain; but there would be some " friction, and roads are both unequal and generally soft, " which latter gives a continued resistance of the same nature " as going up a steep ascent. There is another consideration, " which is, that the carriage, being loaded with the weight of " the engine, would require stronger wheels than usual for " these machines, which would still increase its weight.

" I have taken it for granted all along that 80 lbs. is a " sufficient force to move a common post-chaise, loaded as I " have mentioned, (but without the engine); which, however, " I am by no means certain of. I rather apprehend it will " require that power on a quite plain road, and more upon " acclivities; for four men would be able to exert that force, " and yet could not move the loaded post-chaise at the above " rate; and I observe that horses labour as much in a cart " as they do in a horse-mill, yet they exert near 200 lbs. each " in the latter, at the rate of 1½ miles per hour.

" 31 August, 1784.

" The whole matter seems to turn on an answer to the " question, whether 80 lbs. be a sufficient power to move a " post-chaise on a tolerably good and level road at the rate of " 4 miles in an hour. 2dly. Whether any less surface than " 8 feet exposed to the fire be sufficient to evaporate a cubic " foot of water per hour, without much waste of fuel; which " question seems partly answered by the boiler of our corn-" mill, which has only about 5 feet surface exposed to the " fire for each foot it evaporates per hour; and it evaporates " about 8 cubic feet per cwt., so that by submitting to a waste " of coals, a smaller boiler would do. 3rdly. Whether it will " require steam of more than 1½ times atmospheric density to " cause the engine to exert a power = to 6 lbs. on the inch, " which I fear it will. I think that the cylinder must either

" be made larger, or make more than 60 strokes per minute; " and I do not think the latter plan very advisable, principally " because the rotative motion already turns too fast for the " axle of the chaise, and that it will require more wheels than " two to reduce the motion to the proper velocity. As to " working-gear, stopping and backing, with steering the carriage, I think these articles perfectly manageable.

"The proper place for the engine will be behind the carriage, and to act upon the hind-wheels. Cokes must be " used in place of coals, to prevent the disagreeable circumstances of soot and smoke; but there will be no avoiding the " sulphureous air, which, when going before a gentle wind, " will prove suffocating. The shaking of the carriage will " supersede the necessity of poking the fire, but will be apt " to waste the coals, by making the cokes fall through the " grate before they are consumed. The shaking of the carriage will be apt to derange the joints of the cylinder, &c., " and render them untight; but perhaps some remedy may " be devised for this in construction.

" My original ideas on this subject were prior to my invention of these improved engines, or before the crank or any " other of the rotative motions were thought of. My plan " then was to have two inverted cylinders, with toothed-racks " instead of piston-rods, which were to be applied to two " ratchet-wheels on the axle-tree, and to act alternately; and " I am partly of opinion that this method may be applied to " advantage yet, because it needs no fly, and has some other " conveniences.

"From what I have said, and from much more which a " little reflection will suggest to you, you will see that without " several circumstances turn out more favourable than has " been stated, the machine will be clumsy and defective, and " that it will cost much time to bring it to any tolerable " degree of perfection; and that for me to interrupt the " career of our business to bestow my attention on it would " be imprudent. I even grudge the time I have taken to " write these comments on it. There is, however, another " way in which much mechanism might be saved, if it be in

" itself practicable, which is, to apply to it one of the self-" moving rotatives, which has no regulators, but turns like a " mill-wheel by the constant influx and efflux of steam; but " this would not abridge the size of the boiler, and I am not " sure that such engines are practicable." The remainder of this letter is occupied with the consideration of the arrangements proper to be made with a third party, (not named, but then in the employment of Messrs. Boulton and Watt, and known to have been Mr. William Murdock), in case of his prosecuting the design, which he appears at that time to have warmly entertained, and urged, of making steam wheel-carriages for sale to the public, under a licence from his employers, or in partnership with them.

Again,* "I am extremely sorry that W[illiam] M[urdock] " still busies himself with the steam-carriage. In one of my " specifications I have secured it as well as words could do it " according to my ideas of it; and if to that you add Syming-" ton's and Sadler's patents, it can scarcely be patentable, " even if free of the general specification in the Act of Par-" liament; for even granting that what I have done cannot " secure it, yet it can act as prior invention against anybody " else, and if it cannot be secured by patent, to what purpose " should anybody labour at it? I have still the same opinions " concerning it that I had; but to prevent as much as pos-" sible more fruitless argument about it, I have one of some " size under hand, and am resolved to try if God will work a " miracle in favour of these carriages. I shall in some future " letter send you the words of my specification on that subject. " In the meantime I wish W[illiam] could be brought to do " as we do, to mind the business in hand, and let such as " Symington and Sadler throw away their time and money, " hunting shadows." And, a few days later,† "You are " certainly wrong in your computation of 18 lbs. of water " serving your steam-carriage an hour. At present, where " engines are wrought by condensation, to exert the force " of one horse requires 10 lbs. of coals and 1 cubic foot of

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* 12th September, 1786.

† 23rd September, 1786.

" water per hour; but if steam of double density is used, " as must be the case where there is no condensation, it will " take 20 lbs. of coals and 2 cubic feet of water for each " horse-power. These are the present facts, and I suspect " the age of miracles is past. I am glad, however, that William applies to his business." And, to Dr. Black,* " You " know I have long had plans of moving wheel-carriages by " steam, and I have even described them in one of my " patents some years ago. I believe I shall make some " experiments on them soon, but have small hopes of their " ever becoming useful."

Without, then, trespassing on the undoubted rights of a Stephenson, to whom belongs the chief glory of establishing the magnificent system of railway travelling so characteristic of our days, or on those of others, who have mainly assisted in its development, Mr. Watt may, to a certain extent, be looked upon as the first inventor of practical means for effecting locomotion on land by steam. But it is also undeniable, that his expectations of a profitable result from the employment of such a machine as he had there specified, were at all events very uncertain; that he considered the question as being confined to the movement of carriages upon roads such as were usually employed for traffic throughout the country; and that, although " on a hard smooth plain," where there would be little friction, he seems to have thought it might be practicable enough, yet that, on the whole, under the pressure of the full employment which the rest of his business then daily forced upon him, he both himself declined the prosecution of that newly-imagined branch, and strongly dissuaded Mr. Murdock, who was evidently well disposed to have gone on with it, from doing so.

The experience of more than half a century, and the failure of many inventions tried by others during that period, have since amply demonstrated, that upon the question as so limited in Mr. Watt's contemplation, viz. as it concerned engines to be used upon common roads, his distrust of a successful result was very far indeed from being unfounded. But evidently one great cause,—perhaps the principal one,—of his comparative disregard of the further prosecution of this great practical experiment, as well as of the not less arduous one of steam-navigation, was the constant and advantageous employment of the Soho works in the construction of stationary land engines. Of those the effect was not doubtful, and they required, in order to the perfection of their manufacture, and the consequent completeness of their operation, the best and most undivided attention that their makers were capable of bestowing. It was for no want of discernment of the interesting nature of the problem as he proposed it to himself, nor, as our readers may well suppose, from any deficiency in inventive ingenuity, that he deferred its further solution; for, although he seems to have been rather inclined to prefer "a "short working-beam" to direct action from the piston-rod, and to consider the proper place for the engine to be *behind* the carriage to be propelled, and forming a part of it, still the "violent steam," "let out by successive puffs,"—the copper boiler, "cylindrical, with a number of tubes passing "through, like the organ-pipe condenser,"—the use of "coke "instead of coal," to prevent "the disagreeable circumstances "of soot and smoke," without, however, being able altogether to avoid "the sulphureous air" when going before the wind,—and the shaking of the carriage, "superseding the necessity "of poking the fire, but being apt to waste the cokes, by "making them fall through the grate before they are con-"sumed," form a series of particulars which bring before the mind an image not very dissimilar in its principal features from the well-known locomotive engine of the present day.

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* 5th October, 1786.

It appears also, from one of his letters which we have just quoted,* that in September, 1786, Mr. Watt had a steam-carriage "of some size under hand," and was "resolved to try "if God would work a miracle in favour of these carriages." His experiments of that sort appear to have been interrupted by his journey to Paris in the winter of 1786-7, as well as by his finding that "William [Murdock] applied himself to his

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* To Mr. Boulton, 12th September, 1786.

"business," without further urging the carriage scheme:—and they do not appear to have been afterwards resumed. But his friend Mr. Edgeworth, (whether in consequence of any previous communications with Mr. Watt, or solely from his own ingenuity, which was very considerable, we know not), seems to have made a wonderfully near approximation to the real secret which alone was wanting to bring the whole system into activity, when he wrote, in 1813, "*I have always* "*thought that steam would become the universal lord, and that* "*we should in time scorn post-horses. An iron railroad would* "*be a cheaper thing than a road on the common construction.*"*

Mr. Edgeworth's reflections may, not improbably, have arisen on his perusal of Sir Richard Phillips' 'Morning 'Walk to Kew,' published in the same year, 1813; in which the following remarkable passage occurs:—"I found "delight in witnessing at Wandsworth the economy of horse "labour on the iron railway. Yet a heavy sigh escaped me, "as I thought of the inconceivable millions of money which "had been spent about Malta, four or five of which might "have been the means of extending double lines of iron railway from London to Edinburgh, Glasgow, Holyhead, Milford, Falmouth, Yarmouth, Dover, and Portsmouth. A "reward of a single thousand would have supplied coaches, "and other vehicles, of various degrees of speed, with the "best tackle for readily turning out; and we might, ere this, "have witnessed our mail coaches running at the rate of ten 'miles an hour, drawn by a single horse, or impelled fifteen "miles an hour by Blenkinsop's steam-engine. Such would "have been a legitimate motive for overstepping the income "of a nation; and the completion of so great and useful a "work would have afforded rational ground for public triumph "in general jubilee."†

As a pendant to these annals of some of the earliest attempts, in this country, to effect locomotion on land by steam, we may here record the curious coincidence that, in

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* To Mr. Watt, 7th August, 1813.

† See Smiles' 'Life of Stephenson,' p. 156, where many other interesting particulars are given of the rise and progress of railway locomotion.

1841, the subject prescribed for the Latin Epigram for Sir William Browne's gold medal at Cambridge having been "*Vehicula vi vaporis impulsa*," the prize was gained by Matthew Piers Watt Boulton, of Trinity College, the grandson of Matthew Boulton of Soho. The following is the prize composition, with some slight variations since made by its author:—

" O invidenda cæteris præ gentibus,
  " Dilecta Dîs Britannia,
" Quantis beavit incolas donis tuos
  " Scientiæ progressio!
" Ne jam Sabæa terra veloces equos,
  " Nec jactet Hellas Dædalum;
" Perniciorem machinam invenit tibi
  " Vis ingenî sublimior.
" Ecce ut vaporis currus impulsus flabris
  " In ferreâ cursum viâ
" Tenet, per arva, trans fluenta, viscera
  " Per perforata montium;
" Quàm gaudet intus rapta fulmine ocyor
  " Stupetque plebs motum novum!
" Heu! cum repente illisa desilit rota,
  " Excussa recto tramite,
" Tum dira clades; civibus cives simul,
  " Nasique nasis corruunt.
" Hic crura fracta, hic mœret obtusum caput,
  " Hic oris amissum decus.
" At insciens nos turba, crassa pectora,
  " Cur rem queramur tantulam,
" Planctuque vano gloriis scientiæ
  " Obstemus? Annon convenit,
" Cum citius omnes itur in terras, via
  " Citiore ferri ad Tartara?"

The sense of which may be rendered,—though its elegance is not equalled,—by this English translation:—

" Above all nations, great and free
  " Britannia, lov'd of Heaven!
" What mighty blessings hath to thee
  " The march of Science given!

" Let Greece not boast her Dædalus,
  " Nor Araby her horses:—
" A higher wit invents for us
  " Machines of swifter courses.

" Its iron way athwart the plain
" O'er brooks and rivers steering,
" Through mountains piercing, and again
" From tunnell'd gorge appearing,

" Lo, onward speeds the flying car,
" A steaming, puffing wonder;
" How folks do stare and smile, as far
" They distance thus the thunder!

" But ah! an axle breaks, and then
" Off line the train goes crashing;—
" With dire destruction, men on men,
" Noses on noses dashing.

" Some, broken legs,—some, fractur'd skulls,
" Bewail;—some, loss of beauty:—
" But not of us,—poor, stupid gulls,—
" Is censorship the duty:—

" Of such mere trifles, who complains?
" May Science reign eternal,
" And,—in these railroad days,—run trains
" Express to realms infernal!"

CHAPTER XXVI.

NEW LAMPS — GRAVIMETER — CAOUTCHOUC TUBES — ARITHMETICAL MACHINE — ARTICULATED WATER-PIPE — MACHINE FOR COPYING SCULPTURE — ITS GRADUAL PROGRESS, AND ITS PERFORMANCES — DATES AND EXTRACTS FROM MSS. CONCERNING IT — INTENDED SPECIFICATION OF A PATENT FOR ITS INVENTION — RELATIVE DRAWINGS — TIME EMPLOYED IN ITS OPERATIONS — PERFECTION OF THE WORK DONE — LATER PROCESSES OF A SIMILAR KIND.

BY another of what may be called his mechanical recreations, practised soon after the date of the last of his steam-engine patents, Mr. Watt seems to have realised the idea, made classical by the story of Aladdin, of "New lamps for old." For the following letter to Mr. Argand,* famed for his manufactures of that sort, contains various ingenious suggestions on the subject of better reading-lamps than had before existed; and for a long time lamps were made at Soho on Mr. Watt's principles, which gave a light surpassing both in steadiness and brilliance anything of the kind that had appeared in those comparatively dark ages; and which, indeed, we have seldom, if ever, seen equalled by the elaborate contrivances so much vaunted in our own days of more general illumination.

"I have just seen some of Keir's lamps, but have not seen "them tried; in my opinion, they will be found troublesome, "and subject to be out of order; for the quality of the saline "liquor must be adjusted to a drachm, otherwise they will "not answer: besides, I should suspect that said liquor will "have bad effects upon the oil, or upon the vessels containing "it. I am sure they are clumsy, logger-headed things, top-"heavy, and liable to be overset.

"I have four plans for making lamps with the reservoir "below, and the stem as tall as you please. The first is, by

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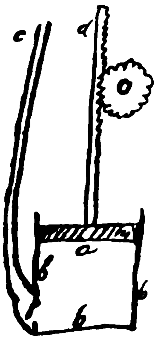
* August 8th, 1787.

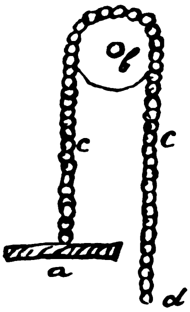
" means of a watch fixed above the reservoir, which shall work " a small forcing-pump, about the size of a quill, at proper " intervals, and keep the burner always supplied; and it may " be so contrived as to stop the water while the oil is within " certain limits in height of the feeder of the burner.

" Second, by means of a pump about 3 inches diameter and " 3 inches stroke, with a *light* piston fixed to it, garnished with " a pliable leather, made to go easy, and perfectly oil-tight. " The stem of this piston, which guides it perpendicularly, " to be pressed down by a clock or timepiece spring in a barrel, " acting on the stem by a wheel and rack-" teeth on the stem; but as the spring will " grow weaker as it unbends, and the pillar " of oil will grow heavier as the piston de-" scends, to regulate these inequalities I " attach to the piston one end of two " heavyish chains, which lie over two pul-" leys, at some considerable height above; " so that, as the piston descends, more " weight of the chains will come to that " side, and assist it in the descent. The " end (*d*) of the chain must be always " heavier than the other, so that it may " keep it tight.



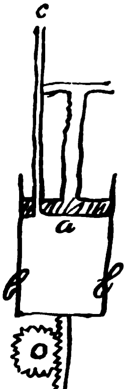
a Piston.
bb Pump.
c Feeding-tube.
d Stem and rack.
e Wheel on spring barrel.

View of Chains and Pulley.



a Piston.
b Pulley.
c Chain.

" Third, instead of making the piston " moveable as in the last, make it fixed; " carry the feeding-pipe out of its upper



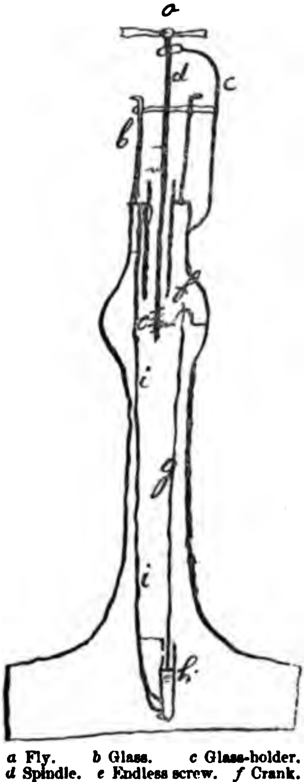
a The piston fixed.
bb The pump moveable.
c The feed-pipe.
d Wheel on spring-barrel.

"surface; let the pump be moveable upwards by means of a "spring and barrel; then, as the spring grows weaker by "unwinding itself, the height of the column of oil and the "weight in the pump will both grow less, in a ratio to which "it is possible to adjust a spring.

"In order to avoid too much height, the pump may be "pulled up by two racks, fixed to the upper edge, and acted "upon by two wheels on the axis of the spring barrel.

"Fourth, last, and best. Let there be placed, about 2 inches "above the upper end of the glass cylinder, a small fly like "that of a smoke-jack, which will turn round very swiftly by "the current of air, and pretty forcibly. Let this fly have a "stem coming down in the inside of the inner cylinder; "at its lower end let there be "an endless screw of one thread, "working into a wheel of 60 or "100 teeth, which will make one "turn for every 60 or 100 revolutions of the fly; on the axis "of this wheel let there be a crank, "(*manivelle*), to which attach the "piston of a small pump about the "size of a goosequill, and ½ an "inch or ⅜ inch stroke, which will "always keep the lamp abundantly "supplied with oil, and a waste-"pipe may convey back the superfluity. I once thought of "making it work a rope-pump, "but the crank will be better, and "amadou will make an excellent "piston; *expertus sum* the amadou.

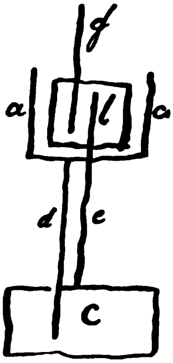
"Now, if this will answer, it "will be the To Καλον, the To "To Μεγιστον, because it will "perform its office by its own "*vis insita.* The fly, indeed, will "darken a small space above it,



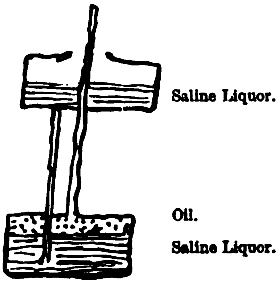
a Fly. *b* Glass. *c* Glass-holder. *d* Spindle. *e* Endless screw. *f* Crank. *g* Pump-rod. *h* Pump. *ii* Feed-pipe.

" but it will serve to amuse people, and consequently will " sell if well made. In short, I like it so well, that if you " will try it, and find it answers, I will go half with you in " a patent for England, if you choose it; otherwise, it is " entirely at your service to make what use of it you please.

" Keir's lamp has, however, one good property which this " will not have, viz., as his pillar of saline liquor grows " shorter, the pillar of oil grows shorter too. Keir's lamp " may be improved in this way:—let *aa* be an open vessel " containing oil, and *bb* be a close vessel containing the same " fluid, *c* a vessel containing air; then the oil in *aa* will " descend into the vessel *c*, by *d*, and the air will ascend by " the pipe *e* into the upper part of *b*, and will force the oil in " it to ascend by the pipe *f* as much above *b* as the surface " of oil in *c* is below the surface in *aa*. By this means you " will be quit of the saline liquor and all its embarrassments, " and you may carry the burner higher than he can; and if " you use a saline liquor in *aa*, you may carry it twice as high " as he does. Q. E. D. *Sat verbum sapienti. Valeant quantum valere possunt*, &c. &c. &c." *



Keir's Lamp.



About a year after the date of the above letter, Mr. Watt made a pretty instrument for determining the specific gravities of liquids, having, he says, improved on a hint he had taken. " It consists of a syphon of two equal

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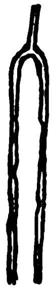
* To Mr. Argand, 8th August, 1787.

" legs, with a tube joined to the bend of it, and a little water " in that tube. One leg being immersed in water, and the " other in the liquid to be examined, by sucking at the " pipe the liquors will both rise to columns proportioned " to their specific gravities; and, if it is about 13 inches " long in the legs, you can easily judge within $\frac{1}{400}$ part " of the specific gravity, or, rather, of the longest column " suspended." *



So late as 1856 we have read the following announcement from St. Petersburg, showing that Mr. Watt's method is not without its followers even in the present era of more exact science:—" A very simple contrivance " has been arranged by A. Meyer, for measuring the specific " gravity of solid and fluid bodies. It consists of a glass " cylinder, (I presume, a precipitating glass), a glass tube in " the form of a syphon, and a brass screw vice for holding the " syphon." †

Little more than a year after the date of the specific-gravity machine, he says that he had " found out a method " of making tubes of the elastic resin, without dissolving it," which recipe he offered to give to his friend the Chevalier Landriani. We have not found this method described in any subsequent letter of Mr. Watt, of which a copy has been preserved; but the subject of it was one which excited considerable interest at that time, and the importance of such tubes for a thousand purposes in science and the arts, is now universally understood. Winch and Cavallo's mode of dissolving caoutchouc in sulphuric æther, and forming tubes by dipping cylindrical clay moulds into the viscous solution, as described in works of that date, received great attention from chemists both in this country and on the Continent, as supplying a great desideratum in the apparatus of the laboratory.‡

The arithmetical machine, on which Mr. Watt says, in 1785, that he had been turning "some of his idle thoughts," he does not appear ever to have prosecuted further than by mentally considering the manner in which he could make it perform the processes of multiplication and division: pro-

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* To Dr. Black, June 8th, 1788. † 'The Times,' 8th March, 1856.

‡ See the 'Travels of St. Fond,' vol. i. pp. 28-34.

cesses which may be held to imply the earlier steps of addition and subtraction. But in a mind such as his, this may safely be presumed to have been already no inconsiderable stage of advancement towards the completion of such a machine. He calls the arrangement of it, as so provided for in his own view, "exceedingly simple;" but speaks modestly of "making an attempt at making it," and of it being only an attempt, from his experience of the difficulties which in mechanics intervene "between the cup and the mouth." Of the wisdom of this caution no one, probably, has been made more fully aware than that ingenious mathematician and machinist of our own time,* who, at great pecuniary cost, and with still greater expenditure of ingenious thought and unwearied application, succeeded in producing a machine which realised even more than Mr. Watt's early announcement contemplated. "I have been turning some of my idle thoughts "lately upon an arithmetical machine; how I shall succeed "I know not, not having made it yet. Its properties are to "be, that when you want to multiply, you first turn up one "figure of the multiplier, you then turn up in their order all "the figures of the multiplicand, and the machine will show "the product by that multiplier; you then turn up the "second figure of the multiplier, and, beginning one place "towards the left hand, you turn up again all the figures of "the multiplicand, and the machine shows the product by "these two figures ready added, and so on for any number of "figures; and it will perform division nearly as easily, with- "out the least calculation or burthen to the memory, other "than to take the figures in their order, beginning at either "end you like. I intend to make an attempt at making it;— "I say an attempt, for though the machine is exceedingly "simple, yet I have learnt by experience that in mechanics "many things fall out between the cup and the mouth." †

Another of his contrivances, happy in its conception, and less difficult of completion than the arithmetical machine would of necessity have been, belongs to the early part of the present century. He was about that time consulted by the company of proprietors of the Glasgow Waterworks, as to a difficulty that had occurred in laying pipes to bring pure spring water across the river Clyde, to the company's engines at Dalmarnock: the channel of the river being there covered with mud and shifting sand, full of inequalities, and subject to the pressure of a considerable body of water. A long and flexible, or rather, articulated suction-pipe, with joints formed on the principle of those in a lobster's tail, and so made capable of accommodating itself to all the actual and possible bendings at the bottom of the river, was at once recommended by him. This crustacean tube, two feet in diameter, and one thousand feet in length, was executed, from his plans and drawings, by Messrs. Boulton and Watt, and was found to succeed perfectly in practice. Although Mr. Watt's services "were induced solely by a desire to be of use in procuring "good water to the city of Glasgow, and to promote the "prosperity of a company which had risked so much for the "public good," they were handsomely acknowledged by the presentation to him of a piece of plate, of the value of one hundred guineas. An account of the flexible water-pipe, accompanied by an engraving of the drawing sent by Mr. Watt, was communicated by the late Sir John Robison to the 'Edinburgh Philosophical Journal' in 1820.*

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* It is scarcely necessary for us to do more than allude to the name of Mr. Babbage; the success of whose difficult pursuits has been so honourable, not only to himself, but also to the mechanical skill of this country, already most highly distinguished in the line of his predilection.

† Mr. Watt to Mr. De Luc, 11th December, 1785.

As he mentioned to Count Berthollet and others of his correspondents, in 1810, Mr. Watt had for several years felt disabled, by the state of his health, from making chemical experiments. But, as he used to say, "without a hobby-"horse, what is life?" and one engrossing occupation, nearly akin to those of his earlier, but what we can hardly call his better days, he also found in gradually perfecting a sculpture-machine: a highly ingenious invention, the idea of which was suggested to him by an implement he had seen and admired in Paris in 1802, where it was used for tracing and multiplying the dies of medals. He foresaw the possibility, if only some mechanical difficulties could be overcome, of so enlarging its powers as to admit of it making in wood or the softer kinds of stone,—nay, even in marble,—copies of works of sculpture, which should be perfectly true to their originals, although of a smaller size; and the imagination of such an exploit seems to have been peculiarly delightful to him, combining as it did some elements of more than one of his other favourite inventions. For the new machine was to do, for solid masses and in hard materials, what his copying-machine of 1782 had already done for drawings and writings impressed upon flat surfaces of paper; while it was necessary that the movements requisite for such a purpose, however complicated they might unavoidably be, should possess great power to act on the obdurate substances subjected to their operation, and be at the same time as entirely under control as if regulated by the gentle energy of the "governor," and acting with all the delicate smoothness of the "parallel motion."

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* 'Edinburgh Phil. Journal,' vol. iii. p. 60.

Of the exact date when he began to construct the first parts of this novelty in the engine department, we have been unable to find any precise note. In 1791 he wrote to Dr. Black that he had been employed for some time on an artificial alabaster, which he had brought nearly to the hardness and transparency of marble,—very much harder than any natural alabaster; and, although he does not mention how this artificial alabaster was made, many of the specimens of the performance of his sculpture-copying-machine were afterwards made of a similar material. The first clear indications that we have met with of his making use of anything that approached to the reality of such a machine, occur in 1807 and 1808, when its construction appears to have been considerably advanced, and he got from London some models to copy,—"small busts of Socrates and Aristotle, and a sleeping "boy, sent by Turnerelli, the sculptor."* He then also ordered some diamond cutting-pencils for what he termed his "Parallel Eidograph."† By April, 1809, he had "made

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* 25th July, 1807.

† November, 1808.

"considerable progress with the carving-machine, and it "seemed necessary to christen it with a Greek name," which to Professor Young, then the accomplished Professor of Greek at Glasgow College, he suggested might be Iconopoia, Iconurga, Iconoglypta, Agalmatopoia, Glyptes, Polyglyptes, Glyptic machine, &c., names to which he afterwards added those of Bust-lathe, Statue-lathe, Pantograph, Double Pantograph, and Double Parallel-lathe. At the same time he got for it, besides gouges and other tools,* "drills made in "steel frames of peculiar construction, to turn with great "velocity and without a shake;" and before the end of May of that year he wrote to his friend, Dr. P. Wilson, that he had now made the glyptic machine polyglyptic, as he could do two or more copies at once, but that it was "still far "short of his ideas: *Ars longa, vita brevis.*" At the same date he informed his son James that since getting his new drill-frames from Manchester, (where they had been made by a skilful workman of the name of Green, under the immediate superintendence of the eminent machinist Peter Ewart), he had tried them only so far as to find that he could work two drills at once, and that he had finished "a "large head of Locke in yellow wood, and undercut, and a "small head of Dr. [Adam] Smith, in ivory, which were both "done on the iron platform: the former not so well," he adds, "as I expect to do, but very well." Other occupations interfered to prevent his doing other carvings at that time.

Six weeks later † he explains to Professor Young the origin of the machine, which was now so far advanced, saying, "There is a machine of the nature of a turning-lathe, which "copies medals and other things in bas-relief; it is called in "France *tour à médailles*, in English the *likeness-lathe*. I "have thought of some improvements on it, which somewhat "extend its uses; (this is at present a secret, which I do not "wish to be spoken of)." Throughout that and the following year he gave various directions to Mr. Murdock, then, as always, his most able assistant at Soho, and to Mr. Peter Ewart at Manchester, who gladly performed for him the like friendly offices, as to the improvement of some of its separate parts, observing to the latter gentleman, "You know my "anxiety to complete it while I can." * To his friends, MM. Levêque and Berthollet also, he described the stage of its progress at which the machine had arrived, and his intention, if he should live to complete it, of communicating a full account of its construction to them.† "I still do a little in "mechanics: a part of which, if I live to complete it, I shall "have the honour of communicating to my friends in "France." And, "I have turned my attention to mechanics "whenever my health permitted, and have, as I hope, nearly "completed a machine which promises to be of use in the "imitative arts, and of which, if I am enabled to complete "it, I shall send you a description; but at present I do not "like to say much upon a matter *in prospectu*—I wish to "speak *de facto*. Whatever may be its success, it has at "least had the good effect of making me avoid many hours "of ennui, by employing my hands when I could not employ "my head, and [has] given me some exercise when I could "not go out." ‡

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* 30th March, 1809.

† 7th July, 1809.

Early in 1811 he wrote to Dr. P. Wilson that his invention continued to succeed, and that he had realised some more of his ideas on the subject, having, by very accurate construction of the machine and adjustment of the tools, &c., overcome the difficulty of getting "the several segments "which form the surface of the bust to meet;" and having executed several small busts in alabaster, he "not being "strong enough to work marble." § "It requires a very ac"curate construction of the machine, and a very accurate "adjustment of the tools, so that their axes may be always "equally distant from each other, as the axes of the pattern "and that of the stone to be cut are." Also, that whereas the specimens Dr. Wilson had seen were done by the cutting-tool and the guide-point moving in parallel lines, which were either straight or circular, and very near each other,—" (an " illustration of Euclid's position, that the motion of a point " generates a line, and the motion of a line generates a sur- " face),"—he had now contrived, though not executed, that the two " points, the guiding and the cutting-point, might " move in any line, straight or crooked, square or diagonal, " so that an inscription might be cut in stone from a drawing " on paper." " The principle is the making a drill, or, in some " cases, a sharp point, walk over the work to be done, in " some given ratio to the motions of a blunt point upon the " pattern; but there is some art," he observes, " in making " a drill, while continually varying its situation, turn round " regularly with any desired velocity; and, on the whole, " there is some art required in the use and application of " the tools, which experience only has taught me."*

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* 3rd May, 1810.

† 14th March, 1810.

‡ 26th December, 1810.

§ 7th March, 1811.

" I was much gratified," writes Dr. Patrick Wilson, " by " the particulars you mentioned concerning your NEW IN- " VENTION, as to which my lips were ever sealed till lately, " that I perceived you had imparted it to the excellent Dr. " Herschel, when with you at Heathfield last summer. We " then, under your patent, talked about it confidentially, " when I was pleased to find your contrivances had been ad- " mired by that friend, who certainly is an excellent judge.

" The first thought of making a cutting or gnawing point " *eat its way*, according to three dimensions, with next to " mathematical precision too, by the turning of a winch, so " as to search for *beautiful forms* into the heart of marbles, " and bring them out into full daylight, is no mean instance " of human sagacity, when *by hook and by crook* the thing has " been so accomplished.

" In all matters of this sort, nine-tenths of the whole " achievement consist in setting before the mind the desider- " atum, though disrobed of the means: I mean in the *factum*, " *puta*, which lies remote from ordinary or common analogies " or associations, and which is the creation of *genius* alone. " The precious germ afterwards requires but the fostering

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* To Mr. P. Ewart, 9th May, 1811.

"care of its parent, to expand till it arrives at fulness of "stature. So have prospered with you, my good friend, "many important inventions; and so, I doubt not, the present one will attain to maturity, to reward your patient "thought."[*]

During the next three years, notwithstanding that the "garret," in which the machine and all its appurtenances were placed, was too hot in the heats of summer,[†] and too cold in the depth of winter,[‡] for the old man to spend much time under its roof, the progress he still was making, and the interest he continued to feel in his curiously skilful process, were attested by "very smooth work on an Egyptian head" he was cutting in mahogany,[§] as well as by "a little figure "of a boy lying down, and holding one arm, very successfully "done; and another boy, about six inches high, naked, and "holding out both his hands, his legs also being separate."

"The band-guide fully answers expectation, and even "follows the motions of the frame faster than I hoped. The "axis bends a little, but not injuriously: it would have been "better a hollow tube. The turned-up edged tool makes very "smooth work on an Egyptian head I am cutting in mahogany. "I cannot manage the twisted tools on wood; they will occasionally set in their claws and split off pieces; but the four-"toothed tool is more manageable, and works faster."[‖]

"But I have been principally employed," he adds, "in "making drawings for a complete machine, all in iron, which "has been a very serious job, as invention goes on very "slowly with me now."

Mr. Murdock soon finished the manufacture of the "new "loom, which looks very scientific and answers its purpose," and Mr. Watt, although still seeing "so much to be done," that he feared he should never accomplish it, or that, when done, it would not be worth the trouble, otherwise than as a mental and bodily exercise, had, by March, 1814, "succeeded "tolerably in making drills for working marble, which has

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[*] 11th May, 1811.

[†] To Mr. P. Ewart, 11th July, 1811.

[‡] To the same, 27th February, 1814.

[§] To Mr. Murdock, 7th December, 1812.

[‖] 7th December, 1812.

"hitherto been a matter of difficulty;" and in the following autumn he wrote to his engineering friend Mr. John Farey, jun., "my machine is now undergoing one of its ultimate "changes, and I expect very soon to have it completed."

Accordingly, in September of the same year, he wrote what appears to have been intended as the title and commencement of a specification of a patent for the invention. The title shows that the description stops short altogether of one of the two species of machines intended to be included in it; it is also obviously incomplete as to many particular proportions and movements of the several individual parts requisite for producing the desired effect. But of all of them, accurate drawings, beautifully made by himself, to a scale, remain; showing that the machines were not only completed in fact, and used in practice, but were also carefully delineated by him, with a view, no doubt, to the relative drawings proper to be attached to such a specification, when delivered in at the Patent Office. The invention having been thus fully completed, and having also been publicly used by Mr. Watt in making the frequent copies of various specimens of sculpture which he, from time to time, distributed to his friends, operated, in more than one instance, to prevent patents being subsequently taken out by others for similar ingenious machines.

The following is the fragmentary description to which we allude, and which is dated September 21st, 1814:—

"Certain new methods, machines, tools, and processes, by "means of which copies, duplicates, or imitations are or may "be executed, cut, carved, or made from the originals, casts, "or models of statues, busts, medallions, seals, dies, moulds, "mouldings, and other carvings, bent, waving, and uneven "surfaces, in or upon some sorts of metal, ivory, bone, horn, "tortoise-shell, wood, marble, and certain other stones and "other substances; so that the said copies are or shall be of "the same, or of some greater or lesser size than the said "originals, within certain limits as may be desired.

"The said machines are of two kinds: First, those which "are intended to form copies of lesser or greater dimensions

" than the originals or patterns; and secondly, those which " are intended to form copies of the same size as the originals " or patterns.

" I begin with the first kind, as being the most simple in " their construction. They consist of a bar, beam, or radius, " having one universal joint or other centre-piece, at one end, " which permits the other end to be moved in any direction, " but will not permit the said bar or beam to turn upon its " own axis in any sensible degree. This beam is connected " by the said joint with one end of an oblong platform, upon " which are guided two tablets, in such manner that they can " be slid to and from the centre without lateral shake. Upon " the said beam are fixed two sockets, each carrying a point " perpendicular to the surface of the said tablets; and the " distance of these points from the centre of motion of the " beam is proportioned to the difference of size which is intended to be made between the patterns and the copy, so " that when the one point called the guide, (which must be " more or less blunted), is drawn backwards and forwards " upon the pattern, (which is fixed upon one of the tablets), " the other point, which is sharp or cutting, may cut or " form a line upon the block or substance to be operated " upon, which is fixed upon the other tablet, similar in its " elevations and depressions to the line traced by the guide-" point."

On one of the drawings Mr. W. has written "This panto-" graph will serve to reduce to $\frac{1}{2}$, $\frac{1}{4}$, and $\frac{1}{8}$. A similar one " will reduce to $\frac{1}{3}$ and $\frac{1}{6}$; $\frac{1}{5}$ and $\frac{1}{7}$ are not so useful, and may " be omitted."*

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* We have also found, in Mr. Watt's handwriting, the following recipes for a " Cement for hardening plaster pat-" terns for the carving machine," of date Nov. 1st, 1810:—

"1. Wax ¾ oz., black rosin 2 oz.; " melt together by a gentle heat.

"2. Wax 1 oz., red-lead or litharge " 1 drachm, rosin 2 oz.; dissolve the " red-lead in the wax by boiling them " till effervescence ceases, then add " the rosin, and, when melted, with-" draw from the fire.

"Wax 1 oz., sulphur 1 drachm; " unite them by a strong heat, and " then add 2 oz. rosin at a lower heat.

"The cement No. 1 melts very fluid " at a low heat, and will do very well " for subjects where small guide-" points are not necessary.

" Where small points are necessary, " No. 2 or No. 3 should be used; but " they do not run so thin, and require " more heat to melt them, especially " No. 2.

"To use these cements, let the

On the backs of letters there remain some notes made by Mr. Watt, of the time occupied by him on several days in succession in making copies of busts with the diminishing machine: one specimen of such rough journals we give here, as indicating the various steps of the process and the comparative time occupied in each. The result was a beautiful head, in alabaster, which still exists in the possession of Mr. Watt's representatives; but it was done before the attainment of all the facility with which some later improvements of the machine enabled the operator to work, and which gave greater rapidity of execution:—

Bust of Sappho, January, 1811.

		Hour.
"Jan. 28.	Making pedestal, 1 hour	1
"29.	Soaking in a strong coat of oil-varnish, and cementing "the bust on pedestal	1
"30.	Cutting out the stone, cementing it and the bust to the "moveable plates, and fixing the centres	3
"31.	Roughing the stone with the tearing-drills to within "the thickness of a halfpenny of the truth. . . .	9
"Feb. 1.	Going over it with the quarter-inch drill to within the "thickness of a thin sixpence	5
"Saturday 2.	Doing the face with the 1-8th drill to the truth, from "the outer corner of one eye to do. of the other "(went too slow)	5
"3.	Doing her breast with do.	1
"Monday 4.	Do. one side of the head	4
"Tuesday 5.	Do. round to within 1-4th of the whole	4
"6.	Quite round, finished the shoulders, removed some of "the steps, or plaits	3
"7.	Cut the crown of the head, undercut the neck, and cut "it off from the centre-piece, repaired the most of it.	3
		39

" plaster pattern be made sufficiently " hot, by placing it before the fire, or " in an oven or stove; then anoint it " with the cement by a brush, and ex" pose it before the fire, or in a stove, " until it absorbs the cement. Give it " in the same manner a second, third, " or even fourth coat, until it has pene" trated at least ¼ inch into the plaster; " remove it from the fire before it has " totally absorbed the last coat, which " it will take in while it cools; and " any which does not seem likely to " be absorbed must be wiped off by a " rag or some tow, and the pattern " laid in a cool place."

This is followed by a "Cement to " fasten the patterns to be cut, to the " tablet of the machine. Wax and " rosin equal parts, say 2 oz. of each, " and, to prevent it cracking in cold " weather, add ½ oz. of a mixture of 3 " parts linseed oil and 1 part of wax, " boiled together until when cold they " become solid."

If it should be discerned by any rigidly censorious eye, that of the Thirty-nine Articles of which this number of hours consists, one is entered to the account on *a Sunday,* we would remark that to Mr. Watt, at that time, a day which passed without "a touch at" his favourite machine might perhaps have been felt as no day of real rest:—but that at all events the time occupied in his brief labour did not equal that of the "Sabbath-day's journey" permitted under the old Judaical dispensation even by those who lived, "after the "most straitest sect, Pharisees." Such philosophical rather than theological employment of the sacred day, however, even if only partial and occasional, will recall to the mind of some of our readers the dying request of Johnson to Reynolds, *that he would not paint on Sundays;* an affecting entreaty, with which, we need scarcely add, that great master very religiously,—and in the end, no doubt, very profitably,—complied.

In 1816, the machine underwent some further improvements, "to assure steadiness in its working," but in August, 1817, Mr. Watt feeling "very languid and unfit for exertion "of any kind," and also experiencing "an occasional dimness "of sight which rendered it at times difficult for him to write "even with spectacles," deferred his superintendence of further changes which were to be made on it, till his return from his tour in Scotland. Some later notices that we have of it from his hand are interesting ones; for in the end of 1817 we find him writing to his friend Chantrey, then near the summit of his fame as the first of British sculptors, "the "diminishing machine is made ready for the trial;" Chantrey replied in the following March expressing the great desire he felt, from the report Mr. Rennie had made to him, to examine the machine; and offering a visit to Heathfield for that purpose in June "if you will be kind enough to encou-"rage me with a promise that I shall then see it." The desired invitation was duly sent; but when Chantrey next passed through Birmingham, (on his return from Scotland in 1818), it unfortunately happened that Mr. Watt was absent from home, and the great sculptor's curiosity therefore remained unsatisfied. The last drawings which Mr. Watt made of any portions of the machine are dated by him February and April, 1818. But it does not appear that, in the last year of his life, he did much more to or with it. It seems by that time to have been nearly or altogether perfect; and his failing strength probably unfitted him for and disinclined him to much exertion even in such old and loved pursuits. Then—

> "Came the blind Fury with th' abhorred shears,
> "And slit the thin-spun life. 'BUT NOT THE PRAISE,'
> "Phœbus replied, and touched my tingling ears."

The sculpture-machine,—the youngest of his mechanical offspring,—the child at once of his old age and of his right hand,*—had always been a great favourite with its venerable progenitor; and it is not difficult to imagine the sort of charm he must have felt in thus "searching for beautiful forms into "the heart of marbles, and bringing them out into full day-"light." The means required in order to such graceful elaboration,—not indeed unattended with difficulties, such as in other undertakings on a more gigantic scale he had been accustomed to meet and to overcome, but free alike from either anxiety or monotony,—gave occasion to many hours of quiet inventive meditation and moderate manual exercise, such as befitted the weight of his years, and did not interfere with the seclusion which he loved. His plastic performances were usually distributed among his intimate friends, with playful apologies for the imperfect skill of *so young an artist*; but some remained in his own possession, and judging from those we have seen, they display not only all the breadth and boldness of outline, but also the more intangible graces of animation and expression possessed by the models from which they were copied. The explanation of his not having made the operations of the machine more widely known at an earlier period is doubtless to be found in the principle he announces in one of his letters to Mr. Magellan, "I never choose

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* See Gen., chap. xxxv., v. 18. "His father called him Benjamin;" "*i. e.*" (adds the marginal interpretation) "the son of the right hand."

"to publish anything which is not complete."* And such completeness as he required went far beyond the ordinary requirements even of the greater number of other accurate and able men.

Those who have witnessed with wonder the perfect truth of the numismatic and artistic fac-simile engravings which by similar glyptic machines a Bate and a Collas have in later days produced; or the economical multiplication of carvings of the most varied and intricate designs, which by the mechanical resources of the present age have been placed within the reach of nearly all who desire to possess them; or the still more admirable and elevated art by which the works of a Cheverton can boast of repeating those of a Canova, a Thorwaldsen, or a Chantrey; may feel interested in becoming acquainted with the results that in the earlier part of the present century were not only theoretically planned but practically attained by the sagacious thought and skilful hand of Watt.

Only one problem, indeed, seems now to remain for such means to achieve; that, viz. of at once copying from the living model, in materials of lapidary hardness. For hitherto, in the object to be copied, an inflexible surface has always been requisite, to enable the guiding-point of the machine to traverse it with firmness. But even this appears to be a difficulty which may in time be overcome; possibly by the *power* being applied solely to the cutting tools, but their direction being regulated by a guiding-point delicately moved over a soft surface, or even in air. It is, perhaps, neither to be expected nor desired that such a process, which, however exact, must still be entirely mechanical, should ever supersede the freedom of inspiration which breathes in the works of a Praxiteles or a Phidias; any more than that the angelic grace of a Raphael or a Correggio, or the glorious colouring of a Titian or a Guido, should be eclipsed by the photographic results of the mere chemical action of light and a combination of optical media. But such mechanical and philosophical contrivances no doubt offer very many additional facilities to the study and attainment of the highest fictile and pictorial art; and certainly, as the means of at once encouraging and gratifying some measure of artistic taste in millions of human beings who must otherwise have been destitute of such innocent and rational enjoyment, their inventors deserve at once our respect and our gratitude.

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* 16th October, 1780.

The classical "garret" and all its mysterious contents,—the Polyglyptic Parallel-Eidograph with its tools and models included,—have ever since been carefully preserved in the same order as when the hand and "eye of the master" were last withdrawn from them, and he crossed the threshold never to return to his work on earth. When last inspected by us, (in 1853), all things there seemed still to breathe of the spirit that once gave them life and energy; and only the presence of some reverend dust silently announced, that no profane hand, forgetful of the "*religio loci*," had been permitted to violate the sanctities of that magical retreat, or disturb the repose of the "wheels," and "drills," and "guiding-points," that have never since been moved.

CHAPTER XXVII.

MR. WATT'S PURSUITS IN RETIREMENT — SECOND JOURNEY TO PARIS — PURCHASES OF LAND IN WALES — THE SNUFF-BOX — EVENINGS AT HOME — SHRIEVALTY OF STAFFORDSHIRE AND RADNORSHIRE — STUDY OF ANGLO-SAXON — POLITICAL SENTIMENTS — ANECDOTES OF HIS SON JAMES — CHARACTERISTICS OF MR. WATT'S CONVERSATION AND FRIENDLY COUNSELS — REVISAL OF ROBISON 'ON STEAM' — EDGEWORTH'S PROPOSAL OF A TUNNEL ACROSS THE MENAI STRAIT.

SUCH were some of the mechanical recreations in which the aged engineer was wont to employ the moderate strength, and the unalterably inventive thoughts, which were still granted to him; blending with them, when at home, the pleasures of horticulture, of happy social intercourse with his neighbours, of most various study, and even of *novel-reading*, —with him always a favourite department of literature!

About the middle of his life, he caused to be engraved on one of his seals, a human eye, with the motto "OBSERVARE;" and to that significant device he ever remained true. When he occasionally visited London, he lost no opportunity of making himself practically acquainted with every new discovery or contrivance of merit, of which any report had reached him: on the ingenious wonders so abundantly exhibited in the shop-windows and warehouses of the metropolis, he gazed with all the delight of a child; and it often happened that their owners, after leading him into conversation, and finding themselves far surpassed in knowledge of their own peculiar pursuits, felt as though they had "entertained an "angel unawares." The orbit of his movements, in short, always bright with his own light, was also marked, long after the period of his passage, by what M. Arago has so characteristically termed "luminous traces."

Sometimes, during the last quarter of a century of his life, he gave to his journeys a somewhat wider geographical range. In 1802, when, during the peace of Amiens, the Continent was for a brief season opened to British travellers, he once more visited Paris; where he renewed his acquaintance with those of his former scientific friends whom time, and the crimes of the revolution, had spared. "We were "very kindly received," he writes to Professor Robison,* "by "my old friends at Paris, M. Berthollet, M. Monge, and "M. de la Place, now become Senators. M. Prony and "M. Hassenfratz were also exceedingly attentive; the former "especially, and seems an exceeding good sort of a man, as "well as a very able mathematician. He appeared to be "sorry that he had not taken more notice of me in his book "on the steam-engine, and has offered to publish, in a succeeding volume, anything I please to furnish him with on "the subject. Many others were very kind. We passed five "weeks there, and, had the weather been warmer, I should "have wished to prolong my stay." * * To the great men of science here named, and the Abbé Haüy, whom he elsewhere includes in the list, must be added another,—perhaps the most interesting of all,—Benjamin Delessert;—a name sacred to the cause of science, of art, and of philanthropy. See his interesting 'Eloge Historique' by M. Flourens, ('Hist. 'de l'Acad. des Sciences,' tome xxii. p. cxix.-cxliii.); where it is said—"Benjamin Delessert passa à Birmingham. * * Le "génie de la mécanique y soumettait à l'homme l'une des "forces les plus puissantes et les plus terribles de la nature. "Benjamin Delessert fut témoin des essais de Watt. * * "Chacun de ces hommes célèbres, comme ces Fées bienfaisantes qu'avait rêvées l'imagination de nos pères, doua "Benjamin Delessert d'un talent particulier. * * Watt le "doua de l'intelligence supérieure des arts mécaniques." In the pursuits of learning and taste, M. Delessert possessed, as all his friends will long remember, multiplied endowments of no less value than that which he thus received at the hand of James Watt. But it is still more worthy of notice, that his path was that of the just, and his death that of the righteous.

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* 26th April, 1803.

The secret of his virtuous life was, at its close in 1847, revealed in these words, made public with his last testament, —(one full of charitable forethought, and munificent care for his fellow-men),—" Après une bonne action, on éprouve un " sentiment de bonheur qui est au-dessus de toute idée: on " dort d'un sommeil paisible, et tous les songes sont agré- " ables!"

We cannot resist the temptation of here inserting a letter which, after his return home, Mr. Watt received from another of his foreign friends, and which speaks with a natural eloquence that must have been irresistible.

" Offenbach, near Francfort, the 4 of March, 1803.

" Much honored Worthy Sir,—would your Genius have " read in my Soul, the very moment I perused the obliging " letter with which you honored the old mother of Sophy " Sternheim, be sure I remembered with blessing the hour " I saw in my little abode *Sir James Watt*, the great bene- " factor of all Centuries to come,—having proved the power " of a mind, Who surly and steadly aply'd his faculties, for " the improvements of Science and Art—the more useful, for " his fellow creatures—Physik and Mecanik—will for ever " bless your name—I was happy to behold you with a New " Conviction, *that the very great man is a very good man to*— " I admire you for the first, but bless and love you for the " second.—May your Sons partake, of your Spirit, and carac- " ter, with wath feelings, should I have seen the worthy " mother of your Childs—and I will ever regret her sikness— " and my old age who has deprived me of the advantage to " become acquainted to her.—I have thanked my god, to " shaked the hand, who has traced the perfection of Steam " Engine—and I pray god, to conserve you Mistriss Watt " and family—in all happiness, far more, then 73 years of " mine. When Dear Sir! you recall Germany, say that you " have there an old friend and well-wisher in

" SOPHY LA ROCHE."

" excuse Dear Worthy sir! all the faults, of the broken " Englisch, I was bold enouhg to write you. Mister Trapp,

" has my everlasting thank for the blessing hour, in wich He
" conducted you to my cottage.—*God bless you.*" *

Mr. Watt also frequently amused himself with tours of observation and enjoyment throughout England, Scotland, and Wales; as well as with agricultural pursuits, and various rural improvements, on some farms in the latter country, which the beauty of the scenery, uniting the softness of the south with some of the wild grandeur of the north, induced him to purchase. He began that species of investment in 1798, on a small scale; and some of the parcels of land which he at first bought were rather widely scattered; but many of them, with large additions made by his son, now form a very extensive estate, the greater portion of which is situated in Breconshire and Radnorshire, between Rhayader and Newbridge, on the most charming part of the course of

> " The sylvan Wye, that wanderer through the woods,"

and of the Ithon, one of the most picturesque of its tributaries.

The simple, but neat and comfortable farmhouse of Doldowlod, (of which a portion yet remains, although now overtopped by another mansion, of greater pretension, lately erected by its side, and communicating with the more modest cottage of earlier days), was the home which congenially received him on his occasional visits. The fine woods which there richly clothe the valley, and agreeably diversify the river and mountain scenery, were chiefly planted under his superintendence and direction;—very many of the trees by his own hand. But, if he thus incurred one portion of the reproach attached by the historian to all who are addicted " agro colendo, aut venando, servilibus officiis in-

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* This quaint epistle is given exactly as it was sent, unaltered in one jot or tittle of its charming *naïveté*. The good old lady who penned it was the authoress of the 'History of Lady 'Sophia Sternheim,' (translated by J. Collyer, 2 vols., 1776); and also of a Journal of Travels in Holland and England, ('Tagebuch einer Reise 'durch Holland u. England, von Sophie 'Wittwe von La Roche;' Offenbach am Main, 1791). We trust that God "conserved" in all peace to the end of her days her honest, ardent, German heart; which united to such admiration of intellectual greatness, the emotions of humble, pious goodness.

"tenti, ætatem agere,"* he was at least exempt from the other; for, unless we except the anecdote of his having in boyhood practised angling from the pier behind his father's house at Greenock, and the metaphor by which he announced his first glimpse and pursuit of the "parallel motion," viz. "I have started a new hare,"† we have not been able to find even the remotest trace of his having, at any time of his life, partaken of the healthful delights to be found in following the sports of the field. In all that concerned the acquisition and beneficial management of their Welsh property, both Mr. Watt and his son derived very material aid from the enlightened judgment and great ability of the late Mr. James Davies, of Moorcourt in Herefordshire; a gentleman whose services to his own and two neighbouring counties were sensibly felt and splendidly acknowledged by their inhabitants. His good memory, indeed, can scarcely fail to descend to posterity along with that of John Kyrle, "the man of "Ross," whose career of active usefulness, (although their tastes were in some respects different), he may be said to have successfully emulated. Mr. Davies died in 1856, aged 78, full of years and of rural honours.

In the happy microcosm in which the great inventor thus lived, "his mind to him a kingdom was;" and his peaceful pursuits were seldom interrupted by any perturbation from without: under his own vine and his own fig-tree, and, for several years at least, with children like olive-branches round about his table, there were none to make him afraid. Even in the busy manufacturing neighbourhood in which he usually resided, not out of reach of some distant echoes of the hammers of Soho, he knew well that "true happiness is of a "retired nature, and an enemy to pomp and noise; it "arises, in the first place, from the enjoyment of one's self; "and, in the next, from the friendship and conversation of a "few select companions: it loves shade and solitude, and "naturally haunts groves and fountains, fields and meadows:

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* Sall. Bellum Catil., cap. iv.
† To Mr. Boulton, 30th June, 1784.

" in short, it feels everything that it wants within itself, and " receives no addition from multitudes of witnesses and spec- " tators."* His first occupation on returning home from any absence, was to walk round his garden, followed by his gardener, surveying his fruit-trees, and commenting on their progress and produce; admiring their blossoms, or examining those fruits, in whose gradual ripening and fall, the wise can trace a natural image of their own maturity and decay.†

If fond of flowers, it must also be confessed that he was not without a secret relish for a certain fragrant weed; and that, too, as prepared in one of its forms now perhaps least fashionable: in other words, he greatly enjoyed the homely solace of an occasional pinch of snuff. This predilection, however, was rarely indulged; as the assiduous legislation of Mrs. Watt denounced the snuff-box. Her habit was to lay violent hands on the offending "mull," wherever she could surprise it, and to carry it away to the safe custody of her china-closet. The philosopher submitted, with his usual placidity; but again, in his own good time, was sure to watch the dame when employed amid her favourite ware, and, while her back was turned, to steal a pinch; or even to recapture the box, and bear off his prize in triumph.

> " Still, as he ran, he look'd behind,—
> " He heard a voice in every wind,
> " And snatch'd a fearful joy!"

Short-lived, alas! it must be acknowledged, were such successes against the enemy: for the name of James Watt adds another to the long roll of those sages who, from Socrates downwards, reversing the doctrine of our great poet and his "Tamed Shrew," have been compelled to pay to their wives the tribute of

> " Love, fair looks, *and true obedience*." ‡

How well he had learned and practised this lesson, one other little anecdote will serve to show:—let philosophical Benedicts of the present day reflect with complacency on their own happier destiny, and profit by their enjoyment of more undisturbed moments! In his "evenings at home," at a certain hour, *fixed by Mrs. Watt*, the door of the dining-room in which she had all too lately left her lord, opened: an old servant appeared, and, altogether disregarding the greater presence in which he stood, with a few active evolutions swept out at once the fire, the lights, and—his master! Adieu, the social *tête-à-tête;* adieu, the book, or soothing reverie of the night; adieu,—some fainter hearts might have said,—to the pursuit of knowledge under such difficulties! But we have it from one who witnessed some of those untimely irruptions, that, as the host slowly rose, he was wont to say with meekness, "*We must go;*"—that still the quiet smile never quitted that benignant countenance,—the serenity of that sweet temper remained undisturbed.

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* Addison, 'The Spectator,' No. 15.

† "Et quasi poma, ex arboribus, " si cruda sunt, vi avelluntur; si ma- " tura et cocta, decidunt; sic vitam " adolescentibus vis aufert, senibus " maturitas."—Cic. 'De Senectute,' cap. xix.

‡ The 'Taming of the Shrew,' Act v. Scene ii.

"His habit was, immediately on rising, to answer all letters "requiring attention; then, after breakfast, to proceed into "the workshop adjoining his bedroom, attired in his woollen "surtout, his leather apron, and the rustic hat which he had "worn some forty years, and there go on with his [sculpture] "machine."* So says a writer who doubtless borrowed his information from a source that he thought might be safely relied on; but the first portion of this statement may be questioned. For, in opposition to the received maxims of longevity, as well as to the doctrine of Dante, who says that—

————"not
"On downy plumes reposing, fame is won,"

Mr. Watt was not a very early riser; and, on many days of his life, the letters that he wrote, would, as we have already mentioned, "alone have furnished full employment "even to an industrious intellect." "The mental fatigue "of Mr. Watt," says Mrs. SchimmelPenninck, "was often "so great, that I have heard he required from nine to "eleven hours' sleep to recruit his powers, and his evenings "were uniformly spent in some light amusing reading."

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* 'Quarterly Review,' vol. CIV. p. 450. 1858.

"He seldom rose very early," says his cousin Mrs. Campbell, "but accomplished more in a few hours' study than ordinary "minds do in many days."*

Twice, a summons to undertake the burdensome honour of the Shrievalty, (of Staffordshire in 1803, and again of Radnorshire in 1816), was met by Mr. Watt with uneasy apprehension, and repulsed with all his energy. At that time he thus almost plaintively stated his own case, with a view, as he says, of "averting so serious a misfortune as serving that office" would have been to him: †—"I am nearly seventy years old; "my health, always precarious, generally confines me to the "house for the greatest part of the winter and spring. I never "was endowed with the speedy decision, firmness of character, "and intrepidity necessary for a public station, and these "qualities have not been augmented by my declining years. "You, as well as any man, know the anxiety and vexation "which I endured for many years from the harassing lawsuits "in which we were unfortunately engaged, and which have "had the effect of making me very unfit for business of any "kind; the powers of my mind are worn out, as well as those "of my body. I have laboured very hard for the public during "the greater part of my life, and hope I have been of some "use. Though I cannot bring forward to the public mind the "'labores, sudores, vigilias,' yet the 'instrumenta artis nos-"træ' are in everybody's hands. I have been useful to the "State in the way Nature intended, and hope I shall not "have a duty imposed upon me I am totally unfit for, nor "have my grey hairs weighed down by a load of vexatious "cares. You know that from my inability to support the "cares of business I have retired from it with a very mode-"rate fortune, in order to enjoy that quiet for which alone "I am now fitted, and which I pray may be undisturbed. "My property in the county is very small,—only a house "and forty acres of poor land, which has *any* value only from "its vicinity to Birmingham.

"The present juncture of affairs seems to require a Sheriff "in the prime of life, possessed of activity and decision, and

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* See above, p. 24.

† To Mr. A. Weston, 15th November, 1803.

" not a timid old man. It is not my part to say who is equal " to the office; but I am fully impressed with a sense of my " own unfitness, and hope I have not deserved so ill of the " nation as to be placed in a situation that might expose my " weakness, or perhaps have worse consequences."

Although every exertion was used by those to whom Mr. Watt communicated his wishes on this occasion, there was at first a great deal of difficulty in getting him excused from serving in the office to which he had been nominated, but to the labour, publicity, and responsibility of which he felt so strong a repugnance; one of the other two names on the list being that of a gentleman who had previously served, and the other that of a baronet who was a half-pay officer, and pleaded his liability to be called into military service. But Mr. W.'s scientific friends, Sir Joseph Banks and the Hon. C. Greville, having used their influence with his Grace the Duke of Portland, then President of the Council, that nobleman, in the most kind and handsome terms, expressed his opinion that Mr. Watt's disposition to preserve that quiet to which he was so well entitled would induce the members of the Council to direct his name to be removed from the list of persons nominated as sheriff. Ultimately a "pocket-sheriff," *i. e.*, a gentleman who was willing to serve, though not nominated, was found by the Lord-Lieutenant. An argument in support of Mr. Watt's claim for release, at that period more valid than any of those at first suggested, (although one that now-a-days would be of little avail), was that he was a member, not of the Established Church of England, but of the Presbyterian Church of Scotland.

In 1816, the circumstances were nearly the same; with the additional weight which his completion of fourscore years had given to the argument arising from declining strength; and no difficulty seems then to have been found in granting the prayer for exemption, uttered by what has been beautifully called "the voice of age, resistless in its feebleness."

"My reasons against serving," he then writes to Mr. Robert Muirheid,* "are, that I have nearly completed my 81st year,

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* 23rd November, 1816.

" have precarious health, and am generally confined to the " house all the winter and spring; that I have spent a long life " in improving the arts and manufactures of the nation; my " inventions at present, or lately, giving employment to [the] " best part of a million of people, and having added many " millions to the national riches, and therefore I have a natural right to rest in my extreme age; that I have no domicile " in the country, nor ever had, and have not been in it more " than two years, and probably never shall; that for these " reasons I was excused serving for the county of Stafford, in " which I live, twelve years ago, and some of them should " weigh more now. Eighty-one is not a period of active life, " and, as far as my personal qualities are concerned, I esteem " myself perfectly unfit; and the consequences of serving " would probably be the sending me a year or two sooner to " the grave."

His apprehensions that the powers of his mind had been worn out, happily remained groundless till the hour of his death. It has been recorded of Dr. Samuel Johnson, in a work which none can read without receiving instruction, and few without experiencing delight, that in the latter part of his life, in order to satisfy himself whether his mental faculties were impaired, he resolved that he would try to learn a new language. For that purpose, he fixed upon the Low Dutch, and continued his application till he had read about one-half of Thomas à Kempis in that unattractive tongue; and, finding that there appeared no abatement of his power of acquisition, he then desisted, satisfied that the experiment had been duly tried.* At a similar period of life, and with a similar view, Mr. Watt resolved to prosecute a like investigation: the language he chose was Anglo-Saxon, and the result was perfectly satisfactory to his mind. Yet his experiment also was, perhaps, liable to the criticism of Burke; who said, on hearing of Johnson's exploit, that from the language selected being so near akin to our own, this was not the most rigorous test that could have been devised. It was indeed scarcely more so than others which Mr. Watt made every month or week throughout his life, even in the most advanced portions of it; but it served the purpose of convincing him of what no one else ever doubted, that his intellectual machinery had been kept "well-oiled, and in good working-order."

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* See Langton's Reminiscences, in 'Boswell's Life of Johnson,' vol. iv. p. 17, ed. Oxford, 1826.

It is right that we should here authoritatively vindicate the venerable subject of our biography from the allegation,—which, however, in these days of rapid political conversion it might be somewhat unsafe to call the *reproach*,—of having been what is termed "a sad radical." There never was a more unfounded impression formed of any man's political sentiments than this; for the wise engineer was throughout his life possessed with the most loyal and constitutional principles; having been, in truth, a plain and homely, but honest and steady *Tory*, of what is called, not without strong reason, and by way of contrast, we suppose, to some modern innovations, the good old *consistent* school. "Our principles," he says, when describing the riots at Birmingham in 1791 and the threats held out by the mob, "which are well known as "friends to the established government and enemies to republican principles, should have been our protection from a mob "whose watch-word was *Church and King;*" and he uniformly expressed his horror at the proceedings of the revolutionists in France, as well as of the unbridled sovereignty of the people in any country. So clear and decided, indeed, were his convictions on such matters, that we should scarcely have thought it necessary to allude to them, had it not been that a prime minister of England was understood to have given utterance, previous to the close of Mr. Watt's life, to the erroneous doctrine already referred to; and we have ourselves, in the present day, heard the same creed repeated by a very able and usually most accurate person, who, however, was on this point no better informed than the Earl of Liverpool had been.

The truth is, that both of those gentlemen, and any others who may have shared their opinion on this subject, led astray by the similarity of name, have confounded Mr. Watt as a politician, with his son Mr. James Watt; who certainly was in his youth carried away, by the enthusiasm then prevalent in what was termed the cause of liberty, to sympathise with the Girondins and Jacobins in Paris, and even to take some open and avowed part in their earlier tumultuous agitations. He was for some time, in company with Thomas Cooper, and Wordsworth the poet, in the habit of associating with many of those men who afterwards attained a dreadful celebrity; and, as Southey has mentioned, was at that time the means (unfortunately for the world!) of preventing a duel between Danton and Robespierre.

"Danton and Robespierre," says Southey, "quarrelled at " one of the political clubs, before the 10th of August: high " words ended in a challenge: they met, and the duel was " prevented by the interference of an Englishman, who went " out as a second to the one, and represented to them how " injurious it would be to the cause of liberty if either of them " should fall. (!) That Englishman was the present James " Watt of Soho, and from him I heard this remarkable fact."*

For another more public exhibition of mistaken zeal displayed in the same cause, Mr. James Watt, jun., and his clever, but eccentric friend Cooper, were thus severely denounced in the British House of Commons:—"Messrs. Cooper " and Watt," said Burke, in the debate on Mr. Sheridan's motion relative to the existence of seditious practices in this country,† "had presented an address, and carried the British " colours in a procession; and on what occasion? The most " infamous that ever disgraced the name of government. A " set of soldiers had been tried by a court-martial, and con- " demned to the galleys. These were fit men for the republicans " of Paris. They might be useful:—though bad soldiers, they " might be good murderers. They were released in contempt " of the Assembly then sitting; brought to Paris, and paraded " in triumph through the hall. On this detestable occasion, " Mr. Cooper and Mr. Watt carried the British colours. They " were locked in the fraternizing embrace. They received " the fraternizing kiss. They went from the hall of the

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* See letter from Southey to A. Alison, Esq., (now Sir Archibald Alison, Bart.), Keswick, April 17, 1833. 'Life of R. Southey,' by Rev. C. C. Southey, vol. vi. p. 209.

† March 4, 1793.

" Assembly to the hall of the Jacobins, where they kissed the
" bloody cheek of Marat;—the iron cheek of Pluto instead of
" Proserpine;—

> " What ardent transports through their bosom ran,
> " Clasp'd in the embraces of the godlike man!"*

The first blood of citizens, however, which the young political enthusiast saw spilt in the gardens of the Tuileries and streets of Paris, sickened him of that "licence" which those wretches meant "when they cried liberty;" and he then endeavoured to mitigate as far as possible that violence of revolutionary rage which he foresaw he must in future deplore.

This partial change of sentiment led to a curious result; for Robespierre having then insinuated in one of his addresses at the Club of the Jacobins, that Cooper and his compatriot were emissaries of Pitt, Mr. J. Watt, with the same fearlessness with which he had previously supported a cause which he imagined to be just, took an instant opportunity of confronting that monster in his own arena:—he indignantly sprang on the tribune, from which by main force he ejected the truculent orator, and in a brief but impassioned harangue, delivered in French, which he spoke with perfect fluency and an excellent accent, completely silenced his formidable antagonist, carrying with him the feelings of the rest of the audience, who expressed their sense of his honest British spirit, in a loud burst of applause! On returning home, having learned, by sure intelligence from one deep in the secrets of his dangerous foe, that his life was no longer safe for a day, he instantly quitted Paris, without even a passport. He succeeded, though with some difficulty, and occasionally at great hazard, in making his way to the south, and never rested till he arrived in Italy. There having devoted himself to other pursuits than politics, and his revolutionary ardour having had time to cool, he saw good cause to shudder at the atrocities committed by those who so lately had been his chosen companions.

"I went over to Paris,"—said the late poet Wordsworth to us, in one of those hours which his presence and converse winged with unfailing delight,—"at the time of the revolu-"tion in 1792 or 1793, and so was *pretty hot in it;* but I "found Mr. J. Watt there before me, and *quite* as warm in "the same cause. We thus both began life as ardent and "thoughtless radicals; but we have both become, in the "course of our lives, *as all sensible men, I think, have done,* good, "soberminded Conservatives!"

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* Speeches of the Right Hon. Edmund Burke, vol. iv., p. 124, ed. 1816.

Such, however, is no doubt the true explanation of the politics of Mr. Watt, senior, having ever been mistaken. But although his own views were uniformly such as we have stated, even he, in judging of those of others who differed from himself, seems to have exhibited all that philosophical moderation which so strikingly characterised his habitual sentiments: as when speaking of Professor Robison he says,—"he entertained a high respect for the constitution of his "country, and detested the novel doctrines of Jacobinism, "which made him pass *censures too severe upon several of the* "*French philosophers,* (*otherwise extremely estimable men, and* "*to whom science is much indebted*), *without duly weighing the* "*circumstances in which they were placed.*"

In the winter of 1813-14, he complied with the request of his distinguished friend, Sir David Brewster, in looking over the articles 'Steam,' and 'Steam Engines,' written by Dr. Robison, for an edition of Dr. R.'s collected works; and he then added to them, with considerable labour, his valuable and well-known annotations as to his own inventions and improvements. His MS. he accompanied by the following interesting letter to Sir David, in which he accurately discriminates between the apparent meaning of some rather obscure expressions that Dr. Robison had used, and that which no doubt they had been intended to bear.

"Heathfield, May, 1814.*

"Dear Sir,—At your request, I have carefully perused my

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* This interesting letter was printed, as many of our readers may be aware, in the collective edition of Dr. Robison's essays on various subjects of 'Mechanical Philosophy,' published, after many years of preparation, in 1822, in four vols. 8vo., under the editorship of Dr., now Sir David

" late excellent friend Dr. Robison's articles 'Steam' and " 'Steam-engines' in the 'Encyclopædia Britannica,' and have " made remarks upon them in such places where, either " from the want of proper information, or from too great a " reliance on the powers of his extraordinary memory, at a " period when it probably had been weakened by a long state " of acute pain, and by the remedies to which he was obliged " to have recourse, he had been led into mistakes in regard " to facts; and also in some places where his deductions " have appeared to me to be erroneous.

" There had been but very little interchange of letters " between us for some years previous to his writing those " articles, and our opportunities of meeting had been rare and " of short duration, and not occupied by philosophical discussions. Had I been apprized of his design, I might at " least have prevented the errors respecting the facts in " which I was concerned; but, upon the whole, it is more " surprising to me that his recollection should have served " him so well in narrating transactions of 30 years' standing, " than that it should sometimes have led him astray. If I " had not retained some memorandums made at the time of, " or soon after, their occurrence, I should myself have felt " great difficulty in recalling to mind the particulars at the " period when I first perused those articles, which was some " time after their publication. I had about that period an " opportunity of personally stating to Dr. Robison some remarks upon them, of which he availed himself to a small " extent in the Supplement to the 'Encyclopædia Britannica,' " and probably would have done so still more, had he been " called upon to remould those articles.

" I have endeavoured to throw most of my corrections into

Brewster. Some years previous to the date of that publication, Mr. Watt presented several of his friends with copies of the Treatises on 'Steam' and 'Steam-engines,' with notes and additions by himself; and reserved his right to reprint his own portions of that work, agreeing that it should not be done for a period of three years after the publication of the 'Mechanical 'Philosophy.' As, however, that time has long since elapsed, and Robison's valuable volumes are not in every one's hand, we need offer no apology for now including Mr. Watt's letter in a work which would have been incomplete without it.

" the form of notes; but in some places I judged it necessary " to alter the text, which alterations I have marked to be " printed in italics, that they may be readily distinguished " from the original. In a few places, I have cancelled part " of the text without any substitution, none appearing to me " to be required. In others, I have left part of the reasoning " unaltered which I did not concur in; as in mere matters of " opinion, where no manifest error was involved, I did not " conceive it proper to introduce my own speculations.

" As the subjects of steam and steam-engines had been " almost dismissed from my mind for many years previous to " my undertaking this revision, I have called in the aid of " my friend Mr. John Southern, and of my son, whose daily " avocations in the manufacture of steam-engines render " them more conversant with some points, to direct my attention to them; and of the former, to examine such of the " algebraic formulæ as appeared essential,—an office for " which he is much better qualified than myself; and he has " accordingly marked those formulæ with his initials.

" I have not attempted to render Dr. Robison's memoir a " complete history of the steam-engine, nor have I even given " a *detailed* account of my own improvements upon it. The " former would have been an undertaking beyond my present " powers, and the latter must much have exceeded the limits " of a commentary upon my friend's work. I have, therefore, confined myself to correcting such parts as appeared " necessary, and to adding such matter as he had not an " opportunity of knowing.

" Here it was my intention to have closed this letter, but " the representations of friends whose opinions I highly " value, induce me to avail myself of this opportunity of " noticing an error into which not only Dr. Robison, but " apparently also Dr. Black has fallen, in relation to *the* " *origin* of my improvements upon the steam-engine; and " which, not having been publicly controverted by me, has, I " am informed, been adopted by almost every subsequent " writer upon the subject of Latent Heat.

" Dr. Robison, in the article 'Steam-engine,' after passing

" an encomium upon me, dictated by the partiality of friend-
" ship, qualifies me as the '*pupil* and intimate friend of Dr.
" 'Black;' a description which, not being there accompanied
" with any inference, did not particularly strike me at the
" time of its first perusal. He afterwards, in the dedication
" to me of his edition of Dr. Black's 'Lectures upon Che-
" 'mistry,' goes the length of supposing me to have professed
" to owe my improvements upon the steam-engine to the
" instructions and information I had received from that gen-
" tleman, which certainly was a misapprehension; as, although
" I have always felt and acknowledged my obligations to
" him for the information I had received from his conversa-
" tion, and particularly for the knowledge of the doctrine of
" latent heat, I never did, nor *could*, consider my improve-
" ments as originating in those communications. He is also
" mistaken in his assertion, (p. 8 of the Preface to the above
" work), that 'I had attended two courses of the Doctor's
" 'lectures;'* for, unfortunately for me, the necessary avoca-
" tions of my business prevented me from attending his or
" any other lectures at College; and as Dr. Robison was
" himself absent from Scotland for four years at the period
" referred to, he must have been misled by erroneous infor-
" mation. In page 184 of the Lectures, Dr. Black says, 'I
" 'have the pleasure of thinking that the knowledge we have
" 'acquired concerning the nature of elastic vapour, in con-
" 'sequence of my fortunate observation of what happens in
" 'its formation and condensation, has contributed in no in-
" 'considerable degree to the public good, by *suggesting* to
" 'my friend, Mr. Watt of Birmingham, then of Glasgow,
" 'his improvement on this useful engine,' (meaning the
" steam-engine, of which he is then speaking). There can
" be no doubt, from what follows in his description of the
" engine, and from the very honourable mention which he
" has made of me in various parts of his lectures, that he did
" not mean to lessen any merit that might attach to me as

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* "Repeated more in detail, with the same erroneous inferences, in his
" Note, vol. i. p. 504.—(J. W.)"

" an inventor; but, on the contrary, he always was disposed " to give me fully as much praise as I deserved. And were " that otherwise doubtful, it would, I think, be evident from " the following quotation from a letter of his to me, dated " 13th February, 1783, where, speaking of an intended publication by a friend of mine on subjects connected with the " history of steam, he says, 'I think it is very proper for you " 'to give him a short account of your discoveries and speculations, and *particularly to assert clearly and fully your sole* " '*right to the honour of the steam-engine.*' * And in a written " testimonial which he very kindly gave on the occasion of a " trial at law against a piracy of my invention in 1796-7, " after giving a short account of the invention, he adds, " '*Mr. Watt was the sole inventor of the capital improvement* " '*and contrivance above-mentioned.*'

" Under this conviction of his candour and friendship, it is " very painful to me to controvert any assertion or opinion of " my revered friend; yet in the present case I find it necessary to say, that he appears to me to have fallen into an " error; and I hope, in addition to my assertion, to make that " appear by the short history I have given of my invention " in my notes upon Dr. Robison's essay, as well as by the following account of the state of my knowledge previous to " my receiving any explanation of the doctrine of Latent " Heat, and also from that of the facts which principally " guided me in the invention.

" It was known very long before my time, that steam was " condensed by coming into contact with cold bodies, and " that it communicated heat to them. Witness the common " still, &c. &c.

" It was known by some experiments of Dr. Cullen and

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[*] See a more full extract from the letter in question printed at p. 15 of Mr. Watt's 'Correspondence on his 'Discovery of the Composition of 'Water,' 1846. It is the same letter in which Dr. Black, speaking of Mr. Watt's discoveries, says, "were you to " be the first publisher of them your" self, you would do it in such a cold " and modest manner, that blockheads " would conclude there was nothing " in it, and rogues would afterwards, " by making trifling variations, vamp " off the greater part of it as their " own, and assume the whole merit " to themselves." Those prophetic sayings were, singularly enough, almost immediately followed by what Robison calls the "*tracasserie*" of Cavendish and Blagden.

others, that water and other liquids boiled *in vacuo* at very low heats:—water [at] below 100°.

“It was known to some philosophers, that the capacity, or *equilibrium* of heat, as we then called it, was much smaller in mercury and tin than in water.

“It was also known, that evaporation caused the cooling of the evaporating liquid, and [of] bodies in contact with it.

“I had myself made experiments to determine the following facts:—

“1st. The capacities for heat of iron, copper, and some sorts of wood, comparatively with water. Similar experiments had also subsequently been made by Dr. Irvine on these and other metals.

“2nd. The bulk of steam, as compared with that of water.

“3rd. The quantity of water which could be evaporated in a certain boiler by a pound of coals.

“4th. The elasticities of steam at various temperatures greater than that of boiling water, and an approximation to the law which it followed at other temperatures.

“5th. How much water, in the form of steam, was required every stroke by a small Newcomen's engine, with a wooden cylinder 6 inches diameter, and 12 inches long in the stroke.

“6th. I had measured the quantity of cold water required in every stroke to condense the steam in that cylinder, so as to give it a working power of about 7 lbs. on the inch.

“Here I was at a loss to understand how so much cold water could be heated so much by so small a quantity in the form of steam, and [I] applied to Dr. Black, as is related in the short history, p. 116, note; and then first understood what was called Latent Heat.

“But this theory, though useful in determining the quantity of injection necessary where the quantity of water evaporated by the boiler, and used by the cylinder, was known, and in determining, by the quantity and heat of the hot water emitted by Newcomen's engines, the quantity of steam required to work them, did not lead to the improve-

" ments I afterwards made in the engine. These improve-
" ments proceeded upon the old-established fact, that steam
" was condensed by the contact of cold bodies, and the later
" known one, that water boiled *in vacuo* at heats below 100°,
" and, consequently, that a vacuum could not be obtained
" unless the cylinder and its contents were cooled, [at] every
" stroke, to below that heat.

" These, and the degree of knowledge I possessed of the
" elasticities of steam at various heats, were the principal
" things it was *necessary* for me to consider in contriving the
" new engine. They pointed out that, to avoid useless con-
" densation, the vessel in which the steam acted upon the
" piston ought always to be as hot as the steam itself:—that
" to obtain a proper degree of exhaustion, the steam must be
" condensed in a separate vessel, which might be cooled to
" as low a degree as was necessary, without affecting the
" cylinder; and that, as the air and condensed water could
" not be blown out by the steam, as in Newcomen's, they
" must be extracted by a pump, or some other contrivance:—
" that, in order to prevent the necessity of using water to
" keep the piston air-tight, and also to prevent the air from
" cooling the cylinder during the descent of the piston, it was
" necessary to employ steam, to act upon the piston, in place
" of the atmosphere. Lastly, to prevent the cylinder from
" being cooled by the external air, it was proper to enclose
" it in a case containing steam, and again to enclose that in
" a case of wood, or of some other substance which trans-
" mitted heat slowly.

" Although Dr. Black's theory of latent heat did not
" *suggest* my improvements on the steam-engine, yet the
" knowledge, upon various subjects, which he was pleased to
" communicate to me, and the correct modes of reasoning
" and of making experiments, of which he set me the ex-
" ample, certainly conduced very much to facilitate the
" progress of my inventions; and I still remember, with
" respect and gratitude, the notice he was pleased to take of
" me when I very little merited it, and which continued
" throughout his life.

"To Dr. Robison I am also bound to acknowledge my "obligations for very much information and occasional assist"ance in my pursuits, and, above all, for his friendship, "which ended only with his life; a friendship which induced "him, when I was beset with an host of foes, to come to "London in the depth of winter, and appear as a witness for "me in a court of justice, whilst labouring under an exces"sively painful disorder, which ultimately deprived him of "life. To the remembrance of that friendship is principally "owing my taking upon myself the office of his commentator "at my advanced age.

"May I request, Sir, that you and the public will permit "that age to be my excuse for any errors I may have com"mitted, and for any deficiencies in the performance of an "office which at no period would have been congenial to my "habits; and allow me to remain, with esteem,

"Dear Sir, your most obedient humble servant, JAMES "WATT."

That the intellectual pleasure derived from the society and conversation of Mr. Watt was of the very highest order, the united testimony of his most intimate friends and associates sufficiently proves. "It was no wonder," as Robison observed of an earlier stage of his life, "that the attachment to Mr. "Watt was strong, when persons of every taste and every "pursuit found in him an inexhaustible fund of instruction "and entertainment." Men of all ranks shared freely in the benefits of his counsels, as well as in the enjoyment of his cheerful cordiality; and alike to the humble artisan as to the aristocrat of rank and talent, the winged hours flew fast in listening to his words of wisdom, delivered in the guise of easy, social, unassuming converse. "I experienced much "pleasure," says St. Fond, "in visiting Mr. Watt, whose "extensive knowledge in chemistry and the arts rendered "his conversation very interesting. His moral qualities, and "the engaging manner in which he expressed his thoughts, "daily increased my respect for him. * * Mr. Watt is a "man of great conceptions. Nature has endowed him with a

" very vigorous mind, and to his other excellent qualities he " joins the mildest and most prepossessing manners, which " interest even at first sight."*

To the very close of his life, this light of his burned steadily and brightly;—he was constantly applied to by those,—(and their name was legion),—who either had invented, or imagined that they had invented, mechanical contrivances of any novelty or utility; and who naturally wished either to obtain the criticism of so experienced a judge, or to bespeak his favour and encouragement. With the greatest candour and most condescending kindness he took pains to caution such persons against their over-sanguine expectations, and also to explain to them some fundamental principles in mechanics, which they too often had overlooked; but which lay, perhaps, at the very threshold of their inquiries, and, if duly considered, might, by stopping their further progress in a particular direction, prevent much subsequent vexation and loss of both time and money.

Thus, to Mr. W. Mitchell, in 1800:—"I am favoured with " your letter of the 5th, and am obliged to you for the intimations it contains, none of which, however, are new to me, " or useful in their present form. To give my reasons would " make a longer letter than I have time or health for at " present. Rotative motions, on the principles of the first " and second you describe, have been tried and abandoned " many years ago. The third (the spiral) is not practicable " as you have drawn it, and would be attended with considerable disadvantages in any way; (it can only make half a " revolution for each stroke of the engine). A more perfect " application of that principle is contained in the specification " of my patent in the year 1781. In respect of the fourth " invention, we use no racks or toothed sectors now; they " are bad things: the method we use is much preferable, " (which you may see at any of our engines). In general, " no rotative motion will answer well that requires the piston " to move with equal velocity in every part of the stroke,

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* 'Travels in England,' ed. 1799, vol. ii. pp. 341, 347.

" and a common crank is nearly the best which has been yet " contrived, or, perhaps, may ever be. I do not by what I " have said mean to discourage you from paying particular " attention to the subject; your ideas are ingenious, and by " further experience you may think upon better things. I " thank you for your attention to me, and the deference you " express to my opinion, and think it my duty to set you " right in a matter which might lead you into fruitless and " expensive experiments."

Such was the sort of counsel, at once kind and judicious, that Mr. Watt was in the habit of giving when consulted by those who aspired to success in his own favourite field of mechanical invention. To many, his experience and sagacity were thus the means of saving much waste of time, the disappointment of their hopes, and even the misery and ruin which too often attend the failure of ingenious but unprofitable projects. In this respect, emphatically, "the alert, kind, bene-" volent old man," as Sir Walter Scott has so well said of him, " had his attention alive to every one's question, his informa-" tion at every one's command."

So also, to the Rev. W. J. Rees, in 1810, in answer to an announcement of " a machine, or rather engine, lately dis-" covered by a friend, an ingenious clergyman of this county, " that gives motion to itself, and can communicate motion " with immense power to any machinery to which it may be " applied; or which may be described as an engine gene-" rating perpetual motion, with as great a quantity of power " as to supersede the necessity of all other expedients;" (!) he writes,—" I am favoured with your letter of the 15th " instant. I have several years ago entirely withdrawn " from business, and am now a very old man, so that I can " be of no use to your friend as an associate or patron. * * " I hope yourself and your friend will excuse my incre-" dulity, but I have very long been satisfied that there can " be no such thing on earth as a perpetual motion, generated " in the machine itself, without the expenditure of some " external power or cause of motion. All the known elements " have, as I believe, been already applied to machinery, and

" you do not infer that your friend has discovered any new " one. It is possible that he may be deceiving himself, and " I would therefore recommend to him, before he proceeds " further, to make a *working* model of his machine, on as " large a scale as he can, and from it to calculate the power " and the probable expense of exciting it, and not to take any " other steps in the business until he is satisfied he is in no " mistake. * *

"I should have very great reluctance to be made the " depositary of the secret of any invention which is not " secured by patent. Should the invention not meet my " approbation, it would lay me under the disagreeable necessity of speaking my sentiments upon it, which might be " construed as dictated by interested motives; or, if the secret " got abroad by other means, I might be blamed for it. Yet, " on the other hand, the inventor might be benefited by my " advice, the fruit of fifty years' experience in mechanics. " On the whole, I wish to decline the confidence; but if I can " give any useful advice, without a full confidence, I shall be " glad to be of use to any ingenious man. If your friend " will answer me by letter the following questions, it may " save him the coming here, should he, after what I have " said, think that proper. Is there no expenditure of any " power or agent extraneous to the machine itself? and, if " so, what may be the expense in money to enable the " machine to raise 30,000 cubic feet of water 1 foot high? " Is that extraneous agent any of the known powers or " elements which have been employed to raise water, or give " motion to machines, such as fire, water, steam, air, or animal " force? Is the machine itself complicated or expensive? I " feel myself very much obliged by the confidence which you " have been pleased to repose in me, and shall endeavour " always to merit your good opinion."

To the extravagant vagaries which occasionally were suggested to him by such projectors, there really were no limits; as when one author, in forwarding to him what he calls his " book on philosophy," observed:—" If the popular or Newtonian system of causes of mundane phenomena and "motions are facts, and things are actuated by them as "principles, I really am not constituted to hear, see, feel, or "comprehend like other persons." A conclusion of the learned writer, the justice of which, (although not exactly in the sense in which he intended it), probably none of our readers will be disposed to deny!

Of another project that was submitted to him about the same time as the clerical engine generating perpetual motion, which was to supersede all other expedients, we must speak with far greater respect. This was Mr. R. L. Edgeworth's idea of making a cast-iron tunnel across the Menai Strait, instead of the plan Mr. Rennie had then proposed of a bridge. "Our old friend," [Mr. Edgeworth], says Mr. Keir in December, 1810, referring to this subject, "rides his hobby-horse "(Mechanics, &c.) with the same spirit that he did forty "years ago." "My scheme is," says Mr. Edgeworth,* "to "join the parts of my fourteen-feet cast-iron cylinders in one "curve, in a dry dock opening into the Menai; when the "joints were sufficiently secured, the whole—let the length "be what it might—would float when both its mouths were "above water. When properly ballasted, I would open the "flood-gates of the dock, tow the tunnel into the river near "the junction of the opposing tides, and sink it upon a bed, "previously constructed, by large stones thrown into the "water, so as to form two walls 16 feet asunder, filled with "sand thrown between them, and supported by a talus of "large stones extending to a considerable distance on each "side of the walls. I do not suppose that these walls would, "at an average, exceed 5 feet high. Secondly;—There is "sufficient depth for vessels to pass over such a tunnel "during neap-tides. Lastly;—I do not believe that rocks or "large stones are driven by the junction of the tides. If "they *are*, it is a serious objection, and most certainly I would "not propose anything till I was master of this part of the "subject. As to the expense, I suppose that it is not difficult "to make a tolerable estimate. The tunnel would cost, at

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* To Mr. Watt, 6th January, 1811.

" 30*l.* per foot, *running*, for 1000 feet, only 30,000*l.* Say " 50,000*l.*:—it would bear but a small proportion to the " expense of a bridge, which is stated at 250,000*l.* No " scaffolding or centres will be wanting; and if it were " determined that rocks are not carried by tides or storms " through the channel, and if, as appears by Mr. Rennie's " report, there is still-water, at times, where the east and west " tides meet, I do not see any great difficulty that could " prevent this vast buoyant mass from floating gently to the " place of its destination, nor in its being gradually sunk " upon its bed in security. The length of the machine will " [not] exceed three times the length of [a first-rate] man-of- " war. Your very sincere and very old friend, RICHARD " LOVELL EDGEWORTH."

" I admire your scheme," replied Mr. Watt, " of putting " the tunnel together in a dry dock, and floating it into its " place; but would not the construction of such a dock prove " very expensive? and would not there be great risk of " breaking some of the joints or pipes in floating it out, or in " laying it upon its bed of sand? which latter would be with " difficulty made of the same form as the tunnel.

" I believe no pipe or cylinder of 14 feet diameter has ever " been cast of any considerable length, such as 9 feet, nor " have I heard of any, even of 3 feet long, beyond 8 feet " diameter. They must therefore, as I apprehend, be made " in panels, 6 or 8 in the circumference, which infers many " joints, flanches, and screws, besides fitting, which is very " expensive. Should any part or joint fail after it is under " water, repairs seem to me nearly impracticable, except by " fishing up the whole. Cast-iron is not perfectly impervious " to water when under considerable pressure. B., W., and " Co. lined a coal-pit 20 fathoms deep with cast-iron cylin- " ders, 1½ inch thick, in panels, I believe, and the water in " many places sprang through the iron where it was " apparently solid. Sea-water acts upon cast-iron without " dissolving it, so as to change its nature, and to make it " more resembling a brittle stone than iron. Bullets fished " up out of the Spanish Armada ship, (sunk at the island of

" Mull), at the beginning of the last century, were so soft as " to be cut with a knife; and I have seen pumps at Wheal " Virgin mine, in Cornwall, that by the vitriolic water had, " in six years, been reduced to that state. In fresh water it " lasts long.

"The expense of such a tunnel I cannot compute, though " I believe there are ingenious founders in England who " could, so far as the castings were concerned; but that, I " should fear, would be the least part of it.

"The tunnel should be laid so low, that vessels, such as " frequent that Strait, could pass over it at low water, or at " least at any time of the tide that would serve them to come " to it, otherwise some unlucky vessel might make a hole in " it. I could not hope that the tunnel could be made so " tight but that it would take in some water; therefore pipes " should be laid within it, and an engine prepared to take out " that water as it came in. There are other objections, some " of which must have occurred to you, and I would trust to " your ingenuity being able to obviate them. On the whole, " my opinion remains unchanged, that if such a work is not " impracticable, it would be extremely hazardous, and what " I could not wish any friend of mine to engage in.

"I trust in your candour to pardon the freedom with which " I criticise the scheme. I should consider myself unpardon-" able, holding the opinions I do, if I disguised them to *you.* " Should you think them not valid, you must place them to " the caution of age and my regard for you. I can have no " other interest in dissuading you from it."

These objections, his friend admitted, were "very solid;" and, although he exercised his ingenuity in meeting them as far as he was able, he expressed himself truly thankful for the trouble which Mr. Watt had taken in detailing his opinion. He was able to add the pleasant intelligence, that although he had been an inventor all his life, he had never injured his fortune, nor, so far as he could tell, hurt his reputation by any scheme, either of a public or of a private nature. "Our " excellent friend, Dr. Small," he says, " early convinced me " that I might easily lessen my happiness by risking any

" material part of my income, and that I could not, by " increasing it sevenfold, add anything to my real enjoy- " ment."

In the days of the magnificent "Britannia Bridge," the description, contained in these letters, of Mr. Edgeworth's ingenious project, will be perused with interest. But the idea can be viewed as, at most, only a very remote step towards the gigantic undertaking so admirably carried out by Stephenson; to whom, in all probability, Mr. Edgeworth's suggestion was quite unknown.

The construction of the Menai Bridge, which forms so conspicuous and beautiful a monument to the intrepid genius and industry of Telford, was commenced in 1818; and on the 30th of January, 1826, the bridge was formally opened to the public. Its length is 1710 feet, or nearly one-third of a mile; and the total weight of iron-work employed in it is above 2186 tons.*

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* See the 'Life of Telford,' pp. 220-229.

CHAPTER XXVIII.

MR. WATT IN OLD AGE — HIS PORTRAITURE BY SIR WALTER SCOTT — MADAME RUMFORD — THOMAS CAMPBELL — LOSS OF FRIENDS BY THEIR PREDECEASE — ROBISON, BLACK, WITHERING, DARWIN — PARTICULARS OF THE DEATH OF DR. BLACK — GREGORY WATT — ROBISON, BEDDOES, BOULTON, PATRICK WILSON, DE LUC — MR. WATT'S OWN LAST ILLNESS — AND DEATH — OFFER OF A BARONETCY — MONUMENTS TO HIS MEMORY — WESTMINSTER ABBEY — HANDSWORTH CHURCH — GLASGOW — GREENOCK — LORD JEFFREY'S CHARACTER OF HIM — PORTRAITS, STATUES, AND BUSTS.

The wonderful memory of Mr. Watt, at once comprehensive and tenacious;—his judgment, as clear as it was sound;—and the charms of his conversation, which captivated all listeners with its "Divine philosophy,"—seem never to have failed on this side of the grave:—a blessing seldom accorded to men of his advanced age, and not more rare than enviable. If his life opened amid clouds and storms, it was destined to close in sunlight and calm; in his peaceful retirement he had found a refuge, whence he could bid farewell alike to the illusions of Hope and the uncertainties of Fortune. He had gained for himself a most honourable place and name among the greatest and worthiest of mankind; he had "permanently "elevated the strength and wealth of this great empire; and "during the last long war, his inventions and their appli-"cation were among the great means which enabled Britain "to display power and resources so infinitely above what "might have been expected from the numerical strength of "her population."* Thus, in happy quiet, he reaped his large harvest of "laurels never sere." Men beheld with veneration approaching to awe, and admiration blended with love, the fine old hero of invention, and giant in intellect, as he awaited that hour which was to raise him above all imperfection, and release him from all sorrow;—even in this life dwelling, as it were,

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* Sir Humphry Davy, when President of the Royal Society; speech at the meeting at Freemasons' Hall, 1824.

——— "inspher'd
" In regions mild of calm and serene air,
" Above the smoke and stir of this dim spot
" Which men call Earth." *

" His friends," says Lord Jeffrey, speaking of a visit which Mr. Watt paid to Scotland, when upwards of eighty, " in that " part of the country, never saw him more full of intellectual " vigour and colloquial animation, never more delightful or " more instructive." † It was then, also, that Sir Walter Scott, meeting him " surrounded by a little band of Northern " literati," saw and heard,—what he felt he was never to see or hear again,—" the alert, kind, benevolent old man, his " talents and fancy overflowing on every subject, with his " attention alive to every one's question, his information at " every one's command."

Here is the rest of that description, known, in all its gay and charming exuberance, wherever the name of Scott is hallowed:—" There were assembled about half a score of our " Northern Lights. * * Amidst this company stood Mr. " Watt, the man whose genius discovered the means of multi- " plying our national resources to a degree perhaps even " beyond his own stupendous powers of calculation and com- " bination; bringing the treasures of the abyss to the summit " of the earth—giving the feeble arm of man the momentum " of an Afrite—commanding manufactures to arise, as the rod " of the prophet produced water in the desert—affording the " means of dispensing with that time and tide which wait for " no man—and of sailing without that wind which defied the " commands and threats of Xerxes himself. This potent " commander of the elements—this abridger of time and " space—this magician, whose cloudy machinery has pro- " duced a change on the world, the effects of which, extra- " ordinary as they are, are, perhaps, only now beginning to " be felt—was not only the most profound man of science—

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* Milton's 'Comus,' l. 3.

† Character of Watt; see p. 529, *infrà*.

"the most successful combiner of powers, and calculator of "numbers, as adapted to practical purposes—was not only "one of the most generally well-informed, but one of the best "and kindest of human beings.

"There he stood, surrounded by the little band I have "mentioned of Northern literati, men not less tenacious, "generally speaking, of their own fame and their own "opinions, than the national regiments are supposed to be "jealous of the high character which they have won upon "service. Methinks I yet see and hear what I shall never "see or hear again. In his eighty-second year,* the alert, "kind, benevolent old man, had his attention alive to every "one's question, his information at every one's command.

"His talents and fancy overflowed on every subject. One "gentleman was a deep philologist,—he talked with him on "the origin of the alphabet as if he had been coeval with "Cadmus; another a celebrated critic,—you would have said "the old man had studied political economy and belles-lettres "all his life;—of science it is unnecessary to speak, it was "his own distinguished walk. And yet, Captain Clutterbuck, "when he spoke with your countryman, Jedediah Cleishbotham, you would have sworn he had been coeval with "Claver'se and Burley, with the persecutors and persecuted, "and could number every shot the dragoons had fired at the "fugitive Covenanters. In fact, we discovered that no novel "of the least celebrity escaped his perusal, and that the "gifted man of science was as much addicted to the productions of your native country, in other words, as shameless and obstinate a peruser of novels, as if he had been a "very milliner's apprentice of eighteen." †

A passage of kindred interest, and, although less commonly adverted to, scarcely, we think, less striking to those who study *the manners of great minds*, occurs in Mr. Lockhart's Life of his illustrious connexion; where he says, "Scott "never considered any amount of literary distinction as

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* Scott has said "eighty-fifth," but this we have ventured to correct.

† Introduction to 'The Monastery,' Abbotsford edition, vol. v., pp. 29, 30.

" entitled to be spoken of in the same breath with mastery in " the higher departments of practical life. * * To have " done things worthy to be written was, in his eyes, a dignity " to which no man made any approach who had only written " things worthy to be read. He, on two occasions, which I " can never forget, betrayed painful uneasiness when his " works were alluded to as reflecting honour on the age that " had produced Watt's improvement of the steam-engine, " and the safety-lamp of Sir Humphry Davy. Such was his " modest creed."*

We believe that Sir Walter could not possibly have felt a more profound reverence for the mighty labours of the great mechanical engineer, than Mr. Watt did for the magical powers of the glorious novelist and poet. Probably each entertained, towards the works of the other, sentiments of greater wonder, and no less affection, than towards any of the more familiar creatures and combinations of his own imaginative or inventive brain. We know not, indeed, whether, if the general suffrages of mankind could be collected as to the respective objects of the two sorts of ambition, the result might, in the present age, be different from that at which Scott seems to have arrived.† But when the exertion of literary power is supported by sound learning, and the exercise of practical art is regulated by the standard of accurate science; when each is employed with such signal success to instruct, to refine, to improve the condition and extend the happiness of mankind; when thus both fairy fiction and stubborn facts are seen alike to be—

—— " but ministers of *Truth*,
" And feed her sacred flame:"—

the balance of comparative merit seems to hang wonderfully even, and the meed of consequent fame which the voice of posterity confers, to be awarded in, probably, a very equal measure.

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* Lockhart's 'Life of Scott,' chap. xxxv. p. 322, ed. 1842.

† "Et qui fecere, et qui facta aliorum scripsere, multi laudantur. " Ac mihi quidem, tametsi haudquaquam par gloria sequatur scriptorem " et auctorem rerum; tamen *in primis* " arduum videtur *res gestas scribere*." Sall. '*Bellum Catil.*' cap. iii.

Compare the picture drawn by so perfect a master of his art as Sir Walter, with the following vigorous sketch, for which we are indebted to a less-practised feminine hand. If its features are scarcely so finished, its outlines seem scarcely less broad and forcible; and we believe the likeness which it expresses to be,—we cannot say more,—as striking and true. " He was one of the most complete specimens of the melan- " cholic temperament. His head was generally bent forward " or leaning on his hand in meditation; his shoulders stoop- " ing and his chest falling in, his limbs lank and unmuscular, " and his complexion sallow. His intellectual develop- " ment was magnificent; comparison and causality immense, " with large ideality and constructiveness, individuality, and " enormous concentrativeness and caution. Whilst Mr. " Boulton's eye and countenance had something of radiance, " Mr. Watt's were calm, as if patiently investigating, or " quietly contemplating his object. His utterance was slow " and unimpassioned, deep and low in tone, with a broad " Scottish accent; his manners gentle, modest, and unassum- " ing. In a company where he was not known, unless " spoken to, he might have tranquilly passed the whole " time in pursuing his own meditations. But this could not " well happen; for in point of fact everybody practically " knew the infinite variety of his talents and stores of " knowledge. When he entered a room, men of letters, " men of science, nay, military men, artists, ladies, even " little children thronged round him. I remember a cele- " brated Swedish artist having been instructed by him " that rats' whiskers make the most pliant painting brushes; " ladies would appeal to him on the best means of devising " grates, curing smoking chimneys, warming their houses, " and obtaining fast colours. I can speak from experience " of his teaching me how to make a dulcimer and improve " a Jew's harp." * Mrs. SchimmelPenninck adds, " Mr. " Watt was ever ready to give information, even to the most " ignorant; and often do I remember his calling me to sit

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* 'Autobiography of Mary Anne SchimmelPenninck,' pp. 40, 41. 1858.

" upon his knee, whilst he explained the different principles " of the hurdy-gurdy or monochord, the harp, and the piano; " or the construction of a simple whistle, or Pan's-pipe, or of " an organ; but he never failed to tell me, that the hurdy-" gurdy was the most venerable in point of antiquity, being " no other than an adaptation of the celebrated monochord " of Pythagoras."

Among the many "celebrities" who, in the last years of its master, visited the retirement of Heathfield, (a small estate near Birmingham and Soho, which Mr. Watt had purchased in 1789, and on which he afterwards usually resided), was the Countess Rumford; with whom, as Madame Lavoisier, Mr. Watt had made friendly acquaintance on his first visit to Paris. It is curious to observe how much scientific history of " 'tis sixty years since," is epitomised in that lady's surrender, and subsequent transfer, of her affections; as well as in one, at least, of her intermediate refusals so to transfer them. In the dawn of her youth and beauty she was happily married to Lavoisier; and, in the noon-tide of his great reputation, made more than half the charm of his delightful home. But that tie having been too early severed by his dreadful death at the hands of the Revolutionists, she chose to marry, " en secondes noces," Thompson Count Rumford, and did *not* choose to marry Dr. Blagden. " Cavendish," says Lord Brougham, " having formed a high opinion of Dr. " (afterwards Sir Charles) Blagden's capacity for science, " settled a considerable annuity on him, upon condition that " he should give up his profession and devote himself to " philosophy; with the *former* portion of which condition the " Doctor complied, devoting himself to the hopeless pursuit " of a larger income in the person of Lavoisier's widow, who " preferred marrying Count Rumford." *

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* 'Lives of Men of Science and 'Letters,' vol. i. p. 445, ed. 1845.

Perhaps the legacy of 15,000*l.* bequeathed to Blagden by Cavendish, which " was generally understood to " have fallen much short of his ample " expectations," (see above, p. 355), failed to the same extent to console him for the Lavoisier loss; although on that head he may possibly have recollected the observation of a great master of the angling art to his scholar,—" Nay, the trout is not lost; " for pray take notice, no man can " lose what he never had."—' The ' Complete Angler, or Contemplative

"Watt himself," says Thomas Campbell, 'the Bard of 'Hope,' writing in February, 1819, "is now eighty-three; "but so full of anecdote that I spent," (in his company at Heathfield), "one of the most amusing days I have ever had "with a man of science and a stranger to my own pursuits."* This is not the only relic which Campbell has left us of his visit to Heathfield and the Soho works, in the very last year of their master's life; for in a little poem which is published in his Life by Beattie,† he follows the example which Darwin had set him, of marrying to immortal verse the somewhat unpoetical performances of the steam-engine:—

"Whirl'd by the steam's impetuous breath
"I mark'd yon engine's mighty wheel,
"How fast it forg'd the arms of death,
"And moulded adamantine steel!

"But soon—that life-like scene to stop,—
"The steam's impetuous breath to chill,
"It needed but one single drop
"Of water cold, and all was still!

"Even so, one tear by * * shed,
"It kills the bliss that once was mine;
"And rapture from my heart is fled,
"Who caus'd a tear to heart like thine!"

And in the summer of the same year, Lord Brougham found Mr. Watt's instructive conversation, and his lively and even playful manner, unchanged.‡

No shade, indeed, seems ever to have passed across the pleasant sunshine of those years of a bright old age, thus prolonged in lustre, save that inevitable one cast by the awful vicissitudes of death and life. But that dread shadow, ever chequering the path of humanity, as some are left a little longer in the "wilderness of this world," and others are taken a little sooner to their eternal rest, falls most frequently and

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'Man's Recreation, by Izaak Walton,' p. 104, ed. J. Major, 1823. Madame Rumford died in 1836, at the advanced age of 81. See the 'Journal 'of Thomas Raikes,' vol. ii. p. 324. 1856.

[*] Beattie's 'Life of Campbell,' vol. ii. p. 345.

[†] Ibid., vol. iii. p. 101.

[‡] 'Lives of Men of Science and 'Letters of the Reign of George III.,' vol. i. p. 385.

darkly across the road of him who has the longest journey to make.

> "The clouds that gather round the setting sun
> "Do take a sober colouring from an eye
> "That hath kept watch o'er man's mortality;
> "Another race hath been, and other palms are won."*

In 1794, Mr. Watt lost his old patron and associate Dr. Roebuck; in 1799, his dear friends Black and Withering; in 1802, Darwin "of the silver song," "almost his most ancient "acquaintance and friend in England." The account which Dr. Robison sent him of the death of Dr. Black is striking and interesting:†—"Colonel Burnet has devolved on me the "mournful task of informing you of the loss of your dear "friend Dr. Black, who died last Friday. Knowing how severely "you must feel this long expected stroke, I should hardly have "accepted of the unpleasant office, were it not in my power to "tell you that his end was such as his most affectionate friend "would wish;—without a groan, and without warning. The "servant had set down his little dinner before him, while he "was busy with a tinman about a pan for warming his mess. "Some time after, a gentleman called; the servant opened the "door, and announced him, the Doctor sitting as usual," * * "in his chair, with his basin of milk on his knees, supported "by one hand, the other leaning on the arm of the chair, and "his chin resting on his breast, as he usually slept after dinner."‡ * * "He made no answer, and John told the "gentleman that his master was asleep, and desired him to "call again; and then went down stairs. But, recollecting "that the Doctor had scarcely had time to prepare and "eat his little mess, and that he never had observed him "fall asleep at dinner before, he went up again, opened "the door, and went forward till he could see his master's "face. He saw him with his eyes shut, and having his "basin of milk, standing between his thighs, supported "by his right hand. Thinking him asleep, and the milk

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* Wordsworth, Ode on 'Intimations 'of Immortality derived from recollections of Childhood.'

† 11th December, 1799.

‡ 18th December, 1799.

" in no danger of spilling, he went back again, and shut the " door.

" But as he was going down stairs, his heart misgave him, " and he returned, and came forward, and called him by name " pretty loud:—got no answer. He then took hold of his " hand, and felt all cold;—in short, 'found,' as he said, 'that " 'his poor master *had given over living.*' The basin was not " fully supported by its position, and was really kept up by " Dr. Black's hand.

" What an enviable close of life to every man! and to our " dear friend it was inestimable. You know that his mind " was elegance itself. He sometimes hinted his uneasiness at " the thought of becoming silly, or slovenly, or squalid, and " even of the last struggle of life; and could not bear the " thought of any indecency of conduct or appearance. His " wish was completely gratified, for life must have ceased " without a pang. The servant told me that for an hour there " was not any change observable on his countenance. Had " skilful people been about him, that sweet countenance might " have been preserved. When I saw him next morning, the " lips had been allowed to contract.

" Dr. Black had been in remarkably good spirits ever since " the beginning of autumn, and was as busy as a man hanging " by his slender thread could be. He was scheming a new " laboratory, to be built by subscription, of which he was to " be the contriver and the architect; and he never was without " some gentle occupation. Elegance and propriety modelled " every thought, and his every sketch has a beauty " which would be highly prized if found at Herculaneum. " *Quando ullum inveniemus parem?*" * * "Any extravasation " in the lungs must have provoked a cough, or a wry face, or " caused some movement. Mr. Geo. Bell, who saw him within " five minutes after his death, (for the servant had seen him " alive about that time before), tells me that there was not the " smallest appearance of his having had an uneasy sensation. " He thinks that it was a paralytic affection of the diaphragm, " of which the Doctor twice before complained to his father, " saying that 'he had caught himself forgetting to breathe.'

" The heart, beating but feebly, ceased at the first omission " of a stimulus from the pulmonic vein, (I think it is called). " I have heard that Col. Townshend died in one of his exhi- " bitions of stopping his heart, and that it was without the " least struggle. So departed our friend." * * " When " I returned from London, at the account which I gave him " of your triumph over Hornblower and Co. he was delighted, " even to tears. He said, 'It is very foolish, but I can't help " ' it, when I hear of anything good to Jamie Watt.' "

" Like you, I may say," replied Mr. Watt, " to him I owe " in great measure my being what I am; he taught me to " reason and experiment in natural philosophy, and was always " a true friend and adviser, whose loss will always be lamented " while I live. We may all pray that our latter end may be " like his; he has, truly, gone to sleep in the arms of his " Creator, and been spared all the regrets attendant on a " more lingering exit. I could dwell longer on this subject, " but regrets are unavailing, and only tend to enfeeble our " own minds and make them less able to bear those ills we " cannot avoid. Let us cherish the friends we have left, and " do as much good as we can in our day!"

Dr. Black's fortune amounted to about 20,000*l.*, and in the disposal which he made of it among his very numerous relatives, he was true to the habits which chemistry had taught him, of minute and exact division; for, the better to enable himself to make the apportionment with due attention to the precise wants and just claims of each of his intended legatees, he divided the whole sum into 10,000 shares, and parcelled them out in what was said at the time to be a most unexceptionable manner.

In 1804, Mr. Watt's favourite son Gregory, the charms of whose presence and extraordinary talents were the ornament and pride of his race, languished and died of that insidious disease which so often destroys the most accomplished and the most lovely; and it was long ere the old man's feelings recovered their wonted tranquillity, which this severe blow had deeply disturbed. The loss of his early and ingenious companion Professor Robison in 1805; of Dr. Beddoes in

1808; of Mr. Boulton in 1809;* of his "dear friend" Dr. Patrick Wilson in 1811, and of De Luc in 1817, (at the great age of 93),† as well as of many others who, though less known in the fields of science, were not less honoured by his cordial attachment, caused him emotions of sorrow to which he has repeatedly given utterance. "By one friend's withdrawing after another," he felt himself "in danger of standing alone among strangers, the sons of later times;" but such events were calls to him also to be ready, and such calls he habitually acknowledged and obeyed. "We cannot help feeling," he writes to Mr. Boulton,‡ "with deep regret, the circle of our old friends gradually diminishing, while our ability to increase it by new ones is equally diminished; but perhaps it is a wise dispensation of Providence so to diminish our enjoyments in this world, that

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* In the notes which he added to the last edition of Professor Robison's Essay on the Steam-Engine, Watt, speaking of Mr. Boulton, expressed himself in these terms:—"In 1774-5, I commenced a partnership with Mr. Boulton, which terminated with the exclusive privilege in the year 1800, when I retired from business; but our friendship continued undiminished to the close of his life. As a memorial due to that friendship, I avail myself of this, probably a last public opportunity, of stating, that to his friendly encouragement, to his partiality for scientific improvements, and his ready application of them to the processes of art; to his intimate knowledge of business and manufactures, and to his extended views and liberal spirit of enterprise, must in a great measure be ascribed whatever success may have attended my exertions."

The same lady who has so well sketched the mien and deportment of Mr. Watt, has left the following equally graphic description of Mr. Boulton:—"He was tall and of a noble appearance; his temperament was sanguine, with that slight mixture of the phlegmatic which imparts calmness and dignity; his manners were eminently open and cordial; he took the lead in conversations, and with a social heart had a *grandiose* manner like that arising from position, wealth, and habitual command. He went among his people like a monarch bestowing largess." Many anecdotes have been preserved of his highly upright and honourable feelings, as well as of his liberality and kindness to all who came within the circle of his influence; and it was truly said of "the princely Boulton," that "he dignified the name of a British manufacturer."—"His forehead was magnificent; the organs of comparison, constructiveness, and of individuality were immense." * * "Amongst those distinguished men, Mr. Boulton, by his noble manners, his fine countenance, (which much resembled that of Louis XIV.), and princely munificence, stood pre-eminently as the great Mæcenas."

† On what appears to have been Mr. Watt's last visit to him at Windsor, in July, 1811, he says he saw "poor Mr. De Luc, who cannot stir from his bed without help, but can sit and write, in which he occupies himself constantly. His memory and faculties seem entire. * * His present work is an account of his travels on the coasts of the Baltic."

‡ 23rd November, 1802.

"when our turn comes we may leave it without regret." So, eight years later, to another correspondent,* "I, in particular, "have reason to thank God that he has preserved me so well "as I am, to so late a period, while the greater part of my "contemporaries, healthier and younger men, have passed "'the bourne from which no traveller returns.' It is, however, a painful contemplation to see so many who were dear "to us pass away before us; and our consolation should be, "that as Providence has pleased to prolong our life, we should "render ourselves as useful to society as we can while we live." And again, when seventy-six years of age,† "On these subjects I can offer no other consolations than what are derived "from religion: they have only gone before us a little while, "in that path we all must tread, and we should be thankful "they were spared so long to their friends and the world."

Indeed, Cicero's arguments for the great and peculiar happiness of old age, beautifully as they are expressed and enforced by him in his celebrated treatise on that subject, must, we fear, be viewed as being more rhetorical than real; and we feel disposed rather to agree, as Mr. Watt seems to have done, in the truth of the less rapturous contentment expressed by another writer, of no less power, whose sentiments come still more home to the heart. "That is the worst part of "life," says Sir Walter Scott, "when its earlier path is trod. "If my limbs get stiff, my walks are made shorter, and my "rides slower: if my eyes fail me, I can use glasses and a "large print: if I get a little deaf, I comfort myself that "except in a few instances I shall be no great loser by "missing one full half of what is spoken: *but I feel the* "*loneliness of age when my companions and friends are taken* "*from me.*"‡

When, in the autumn of 1819, an illness of no great apparent severity,—but which also proved to be of no very long duration,—caused some little anxiety to Mr. Watt's friends, it was soon recognised by himself, with devout resignation, as the messenger sent to summon him away. In contemplation of the solemn event which he perceived was certainly approaching, he calmly conversed on that and other subjects with those around him; and expressed his gratitude to the Giver of All Good, who had so signally prospered the work of his hands, and blessed him with length of days, and riches, and honour.

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* 12th July, 1810.

† January, 1812.

‡ To Miss Edgeworth, 24th April, 1822. Lockhart's 'Life of Scott,' p. 477, ed. 1842.

On the 19th of August, at his own house at Heathfield, he tranquilly expired; and, amid the reverent sorrow of all classes of men, his remains were interred in the parish church of Handsworth, near those of his eminent and venerable associate, Mr. Boulton.

M. Arago, one of the most uncompromising, though, at the same time, the most pure-minded and amiable of republicans, has expressed, in his 'Eloge,' great and rather indignant surprise that "it was not even proposed to make Watt a "Peer." It was certainly not proposed to elevate him to the peerage; nor would that have suited the moderate fortune, the retired habits, and the unambitious character of Mr. Watt. They order these things differently in France, and M. Arago no doubt supposed that what was almost a matter of course in the one country, should be so also in the other. But the English Government was not altogether unmindful of the merits of Mr. Watt; and it was intimated to him, by a friendly message from Sir Joseph Banks, a few years before his death, that the highest honour usually conferred in England on men of literature and science,—(that of a Baronetcy),—was open to him, if he chose to express a wish to that effect. He felt flattered by the intimation, but on conversing with his son, it occurred to both, that there were circumstances and considerations which rendered it ineligible. It was, therefore, allowed to drop; although with a sincere feeling of gratitude on the part of Mr. Watt towards the Sovereign who was prepared so to have honoured him. James Watt would have been the last to join in any disloyal outcry such as we have heard raised in our own time, to the effect that the names of men of genius are more dignified in themselves than when they have received the addition of titles of higher rank; and far distant, we trust, may be the day, when true British hearts will consent either to speak evil of dignities, or to slight the majesty of that regal power which has the constitutional privilege of conferring them. It is true, that

"The rank is but the guinea stamp,—
"The man 's the gowd for a' that;"—

but the pure gold loses nothing of its genuineness by being stamped with the image and superscription of the monarch, and made to pass current in the world with that additional warrant and estimate of its value. Most of the Peers of England have owed their patents of nobility to great talents, or services rendered to their country by their ancestors or themselves; there is no reason why that which adds lustre to the renown of a Nelson or a Wellington should bring discredit on the name of a Watt; and such an elevation, we venture to believe, will never be despised, as one of the rewards of an honest and honourable ambition, except by that most inconsistent of all feelings, "the pride which apes humility."

Not long after Mr. Watt's death, it was understood that Lord Liverpool had publicly expressed regret, that a great opportunity of rewarding merit had been lost. That such were the sentiments of the King, (George IV.), and of the able men who then formed the ministry, became evident from the eagerness with which they entered into the proposal of erecting a public monument to the memory of Mr. Watt, when suggested by his friends, among whom Mr. Charles Hampden Turner took the lead. At the meeting at which provision was made for effecting that national object, the Prime Minister of the Crown occupied the chair, and announced that he was commanded by the King to say that he was most deeply sensible of the merits of Mr. Watt; that he was most anxious that there should be no subscription in testimony of such services in which his name should not appear; and that he was authorised to put down his Majesty's name for 500*l.*; while a Huskisson, a Peel, an Aberdeen, and a Brougham, vied with a Davy, a Mackintosh, a Wilberforce, and a Wedgwood, in expressing their sense of the value of the magnificent inventions with which the name of Watt was associated. "A meeting more distinguished by "rank, station, and talent,"—as it was truly remarked at the time,—"was never assembled to do honour to genius, and to "modest and retiring worth; and a more spontaneous, noble, "and discriminating testimony was never borne to the virtues, "talents, and public services of any individual, in any age or "country." To be so honoured by those most full of honour, and praised by the most praiseworthy, seems to leave nothing more to be desired in the way of posthumous fame, of private respect, or national esteem.

The tribute which a grateful nation has since paid to his memory is thus testified not only by those monuments which in other places throughout the kingdom his countrymen have set up, but also by the colossal statue, from the chisel of Chantrey, erected in Westminster Abbey, by "the "King, his Ministers, and many of the Nobles and Commoners "of the realm;" "NOT," in the eloquent words of Lord Brougham, now for ever associated with the triumphs of the sculptor, "TO PERPETUATE A NAME WHICH MUST ENDURE "WHILE THE PEACEFUL ARTS FLOURISH, BUT TO SHEW THAT "MANKIND HAVE LEARNT TO HONOUR THOSE WHO BEST "DESERVE THEIR GRATITUDE."[*]

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[*] The inscription is as follows:—

NOT TO PERPETUATE A NAME
WHICH MUST ENDURE WHILE THE PEACEFUL ARTS FLOURISH
BUT TO SHEW
THAT MANKIND HAVE LEARNT TO HONOUR THOSE
WHO BEST DESERVE THEIR GRATITUDE
THE KING
HIS MINISTERS AND MANY OF THE NOBLES
AND COMMONERS OF THE REALM
RAISED THIS MONUMENT TO
JAMES WATT
WHO DIRECTING THE FORCE OF AN ORIGINAL GENIUS
EARLY EXERCISED IN PHILOSOPHIC RESEARCH
TO THE IMPROVEMENT OF
THE STEAM ENGINE
ENLARGED THE RESOURCES OF HIS COUNTRY
INCREASED THE POWER OF MAN
AND ROSE TO AN EMINENT PLACE
AMONG THE MOST ILLUSTRIOUS FOLLOWERS OF SCIENCE
AND THE REAL BENEFACTORS OF THE WORLD
BORN AT GREENOCK MDCCXXXVI
DIED AT HEATHFIELD IN STAFFORDSHIRE MDCCCXIX.

Lord Brougham's composition has, indeed, attained the distinction of being declared "beyond all comparison the "finest lapidary inscription in the English language," and is said by the same authority to have, "among its other signal "merits, one which appertains rather to its subject than its "author, that, lofty as is the eulogy, every word of it is "true."[*]

The filial piety of the late Mr. Watt of Aston Hall has liberally and judiciously multiplied those noble statues of his father, which have been justly regarded as Chantrey's greatest works. Thus the Town of Greenock, the University of Glasgow, and the Church of Handsworth, each possesses one of those exquisite pieces of memorial sculpture, truthfully portraying to distant ages the mild, thoughtful, and venerable features of the patriarchal sage, and with silent but impressive eloquence commemorating the birth, the life, the inventions, and the death of James Watt. But there is, perhaps, no one whose name more forcibly illustrates the sentiment of antiquity,—that "of illustrious men the whole world is the "tomb; and not only does the inscription on their own "monuments in their own country bear witness to their "glory, but even in foreign lands an unwritten record of the "mind rather than of any monument remains with every one "for ever."[†]

To him we may, perhaps, be permitted to apply,—in no spirit, we trust, of undue presumptuousness,—what a loving disciple has said of another of the greatest of sages:—

"This was the end, to us, of our friend: a man who was, if "we may be permitted to say so, of all those of his time, (so "far as we have known anything of them), THE MOST VIR- "TUOUS, THE MOST WISE, AND THE MOST JUST."[‡]

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[*] 'Quarterly Review,' vol. CIV. p. 451. 1858.

[†] "'Ἀνδρῶν γὰρ ἐπιφανῶν πᾶσα γῆ "τάφος, καὶ οὐ στηλῶν μόνον ἐν τῇ "οἰκείᾳ σημαίνει ἐπιγραφή, ἀλλὰ καὶ ἐν "τῇ μὴ προσηκούσῃ ἄγραφος μνήμη παρ' "ἑκάστῳ τῆς γνώμης μᾶλλον ἢ τοῦ "ἔργου ἐνδιαιτᾶται."—Thucyd. lib. ii. cap. 43, ed. Arnold, 1830.

[‡] "Ἥδε ἡ τελευτή, ὦ Ἐχέκρατες, "τοῦ ἑταίρου ἡμῖν ἐγένετο· ἀνδρός, ὡς "ἡμεῖς φαιμεν ἄν, τῶν τότε ὧν ἐπειρά- "θημεν ΑΡΙΣΤΟΥ, καὶ ἄλλως ΦΡΟΝΙ- "ΜΩΤΑΤΟΥ, καὶ ΔΙΚΑΙΟΤΑΤΟΥ."—Plat. *Phæd.* cap. lxviii.

"This name," wrote Lord Jeffrey, on receiving the first intelligence of the death of his venerated friend,—and the portraiture he then rapidly drew will always remain unsurpassed in fidelity and power,—"fortunately needs no commemoration of ours; for he that bore it survived to see it "crowned with undisputed and unenvied honours; and many "generations will probably pass away, before it shall have "gathered 'all its fame.' We have said that Mr. Watt was "the great *improver* of the steam-engine; but, in truth, as to "all that is admirable in its structure, or vast in its utility, "he should rather be described as its *inventor*. It was by his "inventions that its action was so regulated, as to make it "capable of being applied to the finest and most delicate "manufactures, and its power so increased, as to set weight "and solidity at defiance. By his admirable contrivance, it "has become a thing stupendous alike for its force and its "flexibility,—for the prodigious power which it can exert, "and the ease, and precision, and ductility, with which it can "be varied, distributed, and applied. The trunk of an "elephant, that can pick up a pin or rend an oak, is as "nothing to it. It can engrave a seal, and crush masses of "obdurate metal before it,—draw out, without breaking, a "thread as fine as gossamer, and lift a ship of war like a "bauble in the air. It can embroider muslin and forge "anchors,—cut steel into ribbons, and impel loaded vessels "against the fury of the winds and waves.

"It would be difficult to estimate the value of the benefits "which these inventions have conferred upon this country. "There is no branch of industry that has not been indebted "to them; and, in all the most material, they have not only "widened most magnificently the field of its exertions, but "multiplied a thousand-fold the amount of its productions. "It is our improved steam-engine that has fought the battles "of Europe, and exalted and sustained, through the late tremendous contest, the political greatness of our land. It is "the same great power which now enables us to pay the "interest of our debt, and to maintain the arduous struggle "in which we are still engaged, [1819], with the skill and

" capital of countries less oppressed with taxation. But these " are poor and narrow views of its importance. It has " increased indefinitely the mass of human comforts and " enjoyments, and rendered cheap and accessible, all over the " world, the materials of wealth and prosperity. It has " armed the feeble hand of man, in short, with a power to " which no limits can be assigned; completed the dominion " of mind over the most refractory qualities of matter; and " laid a sure foundation for all those future miracles of " mechanic power which are to aid and reward the labours of " after generations. It is to the genius of one man, too, that " all this is mainly owing; and certainly no man ever " bestowed such a gift on his kind. The blessing is not only " universal, but unbounded; and the fabled inventors of the " plough and the loom, who were deified by the erring grati- " tude of their rude contemporaries, conferred less important " benefits on mankind than the inventor of our present steam- " engine.

" This will be the fame of Watt with future generations; " and it is sufficient for his race and his country. But to " those to whom he more immediately belonged, who lived in " his society and enjoyed his conversation, it is not, perhaps, " the character in which he will be most frequently recalled, " —most deeply lamented,—or even most highly admired. " Independently of his great attainments in mechanics, Mr. " Watt was an extraordinary, and in many respects a won- " derful man. Perhaps no individual in his age possessed so " much and such varied and exact information,—had read so " much, or remembered what he had read so accurately and " well. He had infinite quickness of apprehension, a prodi- " gious memory, and a certain rectifying and methodising " power of understanding, which extracted something pre- " cious out of all that was presented to it. His stores of " miscellaneous knowledge were immense,—and yet less " astonishing than the command he had at all times over " them. It seemed as if every subject that was casually " started in conversation with him, had been that which he " had been last occupied in studying and exhausting;—such

" was the copiousness, the precision, and the admirable clear- " ness of the information which he poured out upon it with- " out effort or hesitation. Nor was this promptitude and " compass of knowledge confined in any degree to the studies " connected with his ordinary pursuits. That he should have " been minutely and extensively skilled in chemistry and the " arts, and in most of the branches of physical science, might " perhaps have been conjectured; but it could not have been " inferred from his usual occupations, and probably is not " generally known, that he was curiously learned in many " branches of antiquity, metaphysics, medicine, and etymo- " logy, and perfectly at home in all the details of architec- " ture, music, and law. He was well acquainted, too, with " most of the modern languages,—and familiar with their " most recent literature. Nor was it at all extraordinary to " hear the great mechanician and engineer detailing and " expounding, for hours together, the metaphysical theories " of the German logicians, or criticising the measures or the " matter of the German poetry.

"His astonishing memory was aided, no doubt, in a great " measure, by a still higher and rarer faculty,—by his power " of digesting and arranging in its proper place all the " information he received, and of casting aside and rejecting, " as it were instinctively, whatever was worthless or imma- " terial. Every conception that was suggested to his mind " seemed instantly to take its place among its other rich fur- " niture, and to be condensed into the smallest and most con- " venient form. He never appeared, therefore, to be at all " encumbered or perplexed with the *verbiage* of the dull books " he perused, or the idle talk to which he listened; but to " have at once extracted, by a kind of intellectual alchemy, " all that was worthy of attention, and to have reduced it, for " his own use, to its true value and to its simplest form. " And thus it often happened, that a great deal more was " learned from his brief and vigorous account of the theories " and arguments of tedious writers, than an ordinary student " could ever have derived from the most painful study of the " originals,—and that errors and absurdities became manifest

" from the mere clearness and plainness of his statement of " them, which might have deluded and perplexed most of his " hearers without that invaluable assistance.

" It is needless to say, that, with those vast resources, his " conversation was at all times rich and instructive in no ordi" nary degree: but it was, if possible, still more pleasing than " wise, and had all the charms of familiarity, with all the " substantial treasures of knowledge. No man could be more " social in his spirit, less assuming or fastidious in his manners, " or more kind and indulgent towards all who approached him. " He rather liked to talk,—at least in his latter years; but " though he took a considerable share of the conversation, he " rarely suggested the topics on which it was to turn, but readily " and quietly took up whatever was presented by those around " him, and astonished the idle and barren propounders of an " ordinary theme, by the treasures which he drew from the " mine they had unconsciously opened. He generally seemed, " indeed, to have no choice or predilection for one subject of " discourse rather than another; but allowed his mind, like a " great cyclopædia, to be opened at any letter his associates " might choose to turn up, and only endeavour to select, from " his inexhaustible stores, what might be best adapted to the " taste of his present hearers. As to their capacity he gave " himself no trouble; and, indeed, such was his singular " talent for making all things plain, clear, and intelligible, " that scarcely any one could be aware of such a deficiency " in his presence. His talk, too, though overflowing with " information, had no resemblance to lecturing or solemn dis" coursing, but, on the contrary, was full of colloquial spirit " and pleasantry. He had a certain quiet and grave humour, " which ran through most of his conversation, and a vein of " temperate jocularity, which gave infinite zest and effect to " the condensed and inexhaustible information which formed " its main staple and characteristic. There was a little air of " affected testiness, and a tone of pretended rebuke and con" tradiction, with which he used to address his younger friends, " that was always felt by them as an endearing mark of his " kindness and familiarity,—and prized accordingly, far be-

" yond all the solemn compliments that ever proceeded from
" the lips of authority. His voice was deep and powerful,—
" though he commonly spoke in a low and somewhat monotonous tone, which harmonized admirably with the weight
" and brevity of his observations, and set off to the greatest
" advantage the pleasant anecdotes, which he delivered with
" the same grave brow, and the same calm smile playing
" soberly on his lips. There was nothing of effort indeed, or
" impatience, any more than of pride or levity, in his demeanour; and there was a finer expression of reposing strength,
" and mild self-possession in his manner, than we ever recollect to have met with in any other person. He had in his
" character the utmost abhorrence for all sorts of forwardness,
" parade, and pretensions; and, indeed, never failed to put all
" such impostures out of countenance, by the manly plainness
" and honest intrepidity of his language and deportment.

" In his temper and dispositions he was not only kind and
" affectionate, but generous, and considerate of the feelings of
" all around him; and gave the most liberal assistance and
" encouragement to all young persons who showed any indications of talent, or applied to him for patronage or advice.
" His health, which was delicate from his youth upwards,
" seemed to become firmer as he advanced in years; and he
" preserved, up almost to the last moment of his existence,
" not only the full command of his extraordinary intellect,
" but all the alacrity of spirit, and the social gaiety, which
" had illumined his happiest days. His friends in this part
" of the country never saw him more full of intellectual vigour
" and colloquial animation,—never more delightful or more
" instructive,—than in his last visit to Scotland in autumn
" 1817. Indeed, it was after that time that he applied himself, with all the ardour of early life, to the invention of a
" machine for mechanically copying all sorts of sculpture and
" statuary;—and distributed among his friends some of its
" earliest performances, as the productions of a young artist
" just entering on his eighty-third year.

" This happy and useful life came, at last, to a gentle close.
" He had suffered some inconvenience through the summer;

" but was not seriously indisposed till within a few weeks from " his death. He then became perfectly aware of the event " which was approaching; and, with his usual tranquillity and " benevolence of nature, seemed only anxious to point out to " the friends around him, the many sources of consolation " which were afforded by the circumstances under which it " was about to take place. He expressed his sincere gratitude " to Providence for the length of days with which he had been " blessed, and his exemption from most of the infirmities of " age; as well as for the calm and cheerful evening of life that " he had been permitted to enjoy, after the honourable labours " of the day had been concluded. And thus, full of years and " honours, in all calmness and tranquillity, he yielded up his " soul, without pang or struggle,—and passed from the bosom " of his family to that of his GOD.

" He was twice married, but has left no issue but one son, " long associated with him in his business and studies, and two " grandchildren by a daughter who predeceased him. He was " a Fellow of the Royal Societies both of London and Edinburgh, and one of the few Englishmen who were elected " members of the National Institute of France. All men of " learning and science were his cordial friends; and such was " the influence of his mild character and perfect fairness and " liberality, even upon the pretenders to these accomplishments, that he lived to disarm even envy itself, and died, " we verily believe, without a single enemy."

Mr. Watt became a Fellow of the Royal Society of Edinburgh in 1784; of the Royal Society of London in 1785; a Member of the Batavian Society in 1787; and a Correspondent of the Institute of France in 1808. By a spontaneous and unanimous vote, the Senate of the University of Glasgow conferred on him, in 1806, the honorary degree of Doctor of Laws. In 1814, the Academy of Sciences of the Institute paid him the highest honour which it could bestow; it nominated him one of its Eight Foreign Associates.

It may be proper to append to this biography some account of the principal portraits, statues, and busts of Mr. Watt. And first, of the portraits. They are;—

1. A half-length by Sir William Beechey, painted in 1801, and exhibited at the Royal Academy in 1802. "I this day," says Telford, (3rd May, 1802), "paid my respects to you in "the Exhibition room. I think Beechey has succeeded "admirably well."* In 1809 Mr. Watt wrote to one of his friends, "There is no good portrait of me except that painted "by Sir William Beechey, still in his possession, and a copy "of it by himself in Mr. Tuffen's collection, which is more "like than the original, I having sate again for it. Neither "of them," he adds, "is esteemed very like by my son and "others."† On this point his son afterwards rather changed his opinion; and, indeed, came to prefer the portrait in question to any of the other paintings of his father. It may be remembered by many of his friends as having formerly hung in the dining-room at Aston Hall, and is now at Doldowlod, Radnorshire. It has been twice engraved.

The copy which belonged to Mr. Tuffen was, we have ascertained, not included among the pictures belonging to that gentleman which were sold by auction at Christie's in 1818; and we believe it to be the same that was in the possession of the late Charles Hampden Turner, Esq., of Rook's Nest, in Surrey, to whom it was presented by the late Mr. Watt.

2. A miniature enamel by Bone, taken from Sir W. Beechey's portrait in 1805, and executed with all the usual fidelity and success of the artist, so eminent in a line in which few have been able to attain excellence. Size 8×6½ inches. At Doldowlod.

3. A three-quarter, or head size, in crayons, or *pastel*, by Longcastre, an emigrant officer of the Guards of Louis XVI., who was introduced to Mr. Boulton in 1805 by their mutual friend the Abbé de Calonne. Of this, which is a striking

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* Mr. Telford to Mr. Watt, 3 May, 1802.

† Mr. Watt to Dr. Patrick Wilson, 22 May, 1809.

portrait and exact likeness, there is a duplicate by the same artist. One of the pair was presented by Mr. Watt to his cousin Mr. Robert Muirheid, and was lately preserved at Ashcraig, in Ayrshire; the other, which was executed for Mr. Boulton, and long hung in his house at Soho, is now at Haseley Court, Oxfordshire.

4. A three-quarter, or head size, by Partridge, painted (in oils) from Sir W. Beechey's portrait, and also from additional sittings. This good and pleasing likeness was presented by the late Mr. James Watt, junior, to Mr. Barr, the respected medical attendant of his father in his last illness. By him it was bequeathed to the late Dr. John Smith, of Crutherland, in Lanarkshire; on whose death it was sold by auction, and purchased by the Rev. Dr. Fleming, of Glasgow College; who again transferred it to Mr. Robert Napier, the eminent engineer. In his possession, we believe, it now remains.

5. A "bishop's half-length," by Sir Thomas Lawrence, exhibited at the Royal Academy in 1813. This noble work of art, although for some reason or other it seems not to have found due favour in the sight of either Mr. Watt or his son, stands, in our opinion, unrivalled among all the portraits of Watt. It was so great a favourite with the artist who had painted it, that after retaining it for years in his studio, he at last did not part from it without much reluctance. He considered the head *the finest he had ever painted:* the ease of the attitude, and the drawing and flesh-tints of the hands, are also wonderfully beautiful and true to nature. The posture is sitting; the head slightly bowed with age; the eyes are looking full at the spectator; the hair is silver-white,—(Mr. Watt was then in his seventy-eighth year);—the expression of the countenance is animated, yet calm, mild, and thoughtful. This portrait was bequeathed by the late Mr. Watt, of Aston Hall, to his god-son Matthew Piers Watt Boulton, "to be by "him preserved in his Gothic Library, at Tew Park, along "with the portraits of his late grandfather and father, and to "accompany those portraits as heir-looms in his family." It has been engraved in mezzotint by the late Mr. Charles Turner, but impressions of the plate are rare.

6. A three-quarter, or head size, by Sir Henry Raeburn. Neither Mr. Watt, nor his son, having felt perfectly satisfied with any of the portraits previously painted of him, he sat for this when in Edinburgh in November, 1815, being then seventy-nine years of age. "Raeburn," he says, "has "painted a head of me, which, though it does not come up to "my ideas of my own face, is more conformable to them than "any of the others, and by my friends is said to be a good "likeness." And again, "My Edinburgh picture is come "home, and is thought like, only it frowns too much." This portrait, of which a copy was made by the artist, with Mr. Watt's full approval, for his friend the late Mr. Rennie, is now at Heathfield, and is a finely coloured and forcible picture.*

7. A three-quarter, or head size, by Mr. J. Graham Gilbert. "Taken," says the artist, "from Chantrey's bust and Sir "Thomas Lawrence's portrait." Mr. Gilbert presented this work to the Hunterian Museum in the University of Glasgow, where it now hangs; and he has furnished us with a strong proof of his success in producing a likeness, in the anecdote, that "when Mrs. Watt saw the portrait in the Museum, she "thought it so like, that she immediately ordered one pre-"cisely the same for herself; which was lately at her place "[Heathfield] near Birmingham."

In 1809, Mr. John Henning of Edinburgh made a large chalk drawing of Mr. Watt, (a head), for the late Lord Jeffrey, as well as a small copy of it for another gentleman; also two or three enamel casts on an enamel ground, made in a furnace, and intended, we presume, to emulate the excellent works of Tassie in that style. The smaller drawing we have never seen; of the larger one, which is still preserved in Edinburgh, and of which some of the features possess considerable likeness to those of Mr. Watt, the general effect is, nevertheless, heavy, and not very pleasing. The same may, we believe, be said of the enamel casts.

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* The finest works of Raeburn need not fear comparison with those of any artist of modern times, and do the highest honour to that country which produced a Jameson, "the first "true portrait-painter of the isle." "Raeburn," says the biographer of Wilkie, "even while Wilkie studied "in Edinburgh, stood at the head of "his art in the North, undisturbed "by a rival. His style was manly "and vigorous; he entered little into "the detail of the face, but called the "mind into the countenance, and "fixed it there with a happiness of "expression in which he found few "who shared. He lived in affluence "and hospitality, visited and dined "among the first-born of the land, "and had a residence and a gallery "of a splendour new to Scottish art." (Life of Sir David Wilkie, by Allan Cunningham, vol. i. p. 56.) "There "is much resemblance," said Wilkie himself, "between Velazquez and the "works of some of the chiefs of the "English school; but, of all, Rae-"burn resembles him most,—of whose "square touch in heads, hands, and "accessories, I see the very counter-"part in the Spaniard." (*Ibidem*, vol. ii. p. 504. See also Sir Edmund Head's 'Handbook of Painting of the 'Spanish Schools,' p. 155, ed. 1854.)

In 1818, J. Jackson, the Royal Academician, made a drawing of Mr. Watt from sittings, and also one from Chantrey's bust; the former was thought creditable to him as an Exhibition drawing. It is a sketch in pencil, on drawing paper, front view, with the face carefully finished in water-colour; size, 8½ × 6½ inches. As was to be expected from the well-known powers of the artist, it is a clever and forcible drawing; but the expression is, as Mr. Watt observed, rather "peevish," and, therefore, unpleasant. It is now at Doldowlod.

The most pleasing pencil drawing of Mr. Watt, which at the same time possesses the greatest resemblance, is, singularly enough, one that was made not from the life, but from Chantrey's bust, by an artist, Mr. Edward Finden, who, (so far as we know), never saw Mr. Watt. This spirited sketch was engraved by Mr. Finden with equal success, and forms the frontispiece to the present volume. It has already appeared with the Translation of M. Arago's 'Eloge,' in 1839, as well as with the 'Correspondence on the Discovery of the Composition of Water,' in 1846; and with the 'Origin and Progress of the Mechanical Inventions of James Watt,' in 1854; being, of all the engravings of his father, that by which the late Mr. Watt wished that his image should be conveyed to posterity:—a reason which the author trusts will be accepted as a sufficient apology for the somewhat unusual repetition of the same engraving in four successive works. The original drawing is preserved at Doldowlod.

The full-length statues of Watt, by Chantrey, are five in number. Two of them are of colossal size: the one, of marble, in Westminster Abbey; the other, of bronze, in George's Square, Glasgow. The other three, those, viz. in Handsworth Church, Glasgow College, and Greenock Library, are all of marble, and of the size of life. In all, the well-known attitude, (a sitting one), the arrangement of the drapery, and the contemplative expression, are nearly alike; and they all are eminent examples of that truthful style of portrait-sculpture for which the master who modelled them was so remarkably distinguished. But in point of success in conveying the expression of gracious ease, and of the mild yet thoughtful repose of a deeply-fathoming intellect, the preference must, it is usually confessed, be given to those which are not colossal. Of those three, that in Handsworth Church appears to us to impress the spectator most strongly with the blended majesty and sweetness which breathed in the features of the original. Independent of its own exquisite grace as a work of art, it is also seen to the greatest advantage, in a chapel built expressly for its reception and preservation, in which the details of space, elevation, and light were all carefully adapted to the designs and wishes of the sculptor. And it adds in no small degree to the feeling of solemn interest of which all are conscious in beholding so noble a monument, to learn that in the vault beneath repose the remains of him who, while he lived among us, " SIC SEDEBAT."

Of the beautiful marble busts of Mr. Watt by Chantrey, the first of which was exhibited at the Royal Academy in 1815, and in finishing which the sculptor said, " I have done " the best in my power," we have seen seven; besides three others, scarcely inferior, completed, after the death of Sir Francis, but from his model, and with the consent of his executors, by his very able assistant Mr. Heffernan.

From a mould which Chantrey made of the bust, he took several good casts, which were chiefly distributed by Mr. Watt and his son among their personal friends. But, as in the case of Sir Francis's equally fine model of the head of Sir Walter Scott, " the bust was pirated by Italians; and England and " Scotland, and even the Colonies, were supplied with unper-" mitted and bad casts, to the extent of thousands,—in spite "of the terror of an Act of Parliament."* On receiving one of the genuine casts, fresh from the atelier of Sir Francis, Sir Walter Scott wrote to Allan Cunningham,—"I have to "thank you for sending me in safety a beautiful specimen of "our English Michael's talents, in the cast of my venerable "friend Mr. Watt: it is a most striking resemblance, with all "that living character which we are apt to think life itself "alone can exhibit."†

When the Art-Union employed the late Mr. Wyon to execute a medal in honour of the memory of Sir Francis Chantrey, the design adopted,—a simple and expressive one,—was, for the obverse, a head of the sculptor, with the legend—

"CHANTREY SCULPTOR ET ARTIUM FAUTOR:"—‡

for the reverse, a copy of his greatest work. The work selected was the monument to James Watt;—with the inscription—

"WATT
"FRANCISCI CHANTREY OPUS."

The medal was finished by Wyon with all the force and facile elegance of his admirable style, and thus forms a graceful memorial of those whose names it bears.

We must not conclude this notice without referring to some of the most exquisite of all the likenesses of Mr. Watt, viz. the reduced copies of Chantrey's bust which Mr. Cheverton has, with great ingenuity, executed in ivory. They possess the most perfect and truthful adherence to their original, as well as the most finished execution, that it seems possible to desire; and it gives an additional interest to those beautiful *morçeaux*, that they are produced by a process similar to that which Mr. Watt himself invented.§ Indeed, Mr. Watt, in

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[*] Sir F. Chantrey to Sir R. Peel, 26th January, 1838. Lockhart's 'Life 'of Scott,' chap. lxxxiv. p. 763, ed. 1842.

[†] 'Life of Scott,' chap. l. p. 440, ed. 1842.

[‡] See the obverse of this medal engraved at p. ix. of 'Winged Words 'on Chantrey's Woodcocks,' 1857.

[§] See above, pp. 468-480, on the Machine for Reducing and Copying Sculpture.

From the Medal by Wyon.

Struck for the Art Union of London.

[illegible]

sending to his learned friend the late Mr. Thomas Thomson of Edinburgh, what he calls a specimen of his attempts at carving,—" a wooden John Locke, *without Human Under-" standing*, valuable only as a faithful copy of an ivory medal-" lion done from the life,"—says, " if I live, I still hope to be " able to produce a reduced copy of Chantrey's bust of myself, " fit for a chimney-piece ; " adding, with a very sincere, but a very unnecessary scruple of his usual modesty,—" as I do not " think myself of importance enough to fill up so much of my " friends' houses as the original bust does." *

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* Mr. Watt to Mr. Thomas Thomson, 26th May, 1818.

END OF THE LIFE OF WATT.

APPENDIX.

No. I.

LIST OF THE WORKS OF DENYS PAPIN.

1. *Separate Substantive Publications.*

1. Nouvelles experiences du vuide, avec la description des machines qui servent à les faire. 4to. Paris, 1674. (Dedicated "à Monsieur Hugens de Zulichem.")

2. A new Digester, or Engine for softening bones; containing the description of its make and use in these particulars:—viz. Cookery, Voyages at sea, Confectionary, Making of Drinks, Chymistry, and Dying. With an account of the Price a good big Engine will cost, and of the Profit it will afford. By Denys Papin, M.D., Fellow of the Royal Society. London, Printed for Henry Bonwicke, at the Red Lyon, in St. Paul's Churchyard. 1681. 4to.—(First edition of the curious work in question, and printed in consequence of an order of the council of the Royal Society, dated 8th December, 1680, and signed Chr. Wren.)

3. La manière d'amollir les os, et de faire cuir toutes sortes de viandes en peu de temps et à peu de frais, avec une description de la machine dont il faut se servir à cet effet. Paris, 1682. 12mo.—(Erroneously stated by Ducoux to have been the first edition. A still later edition, also in French, was published at Amsterdam, in 1688, in 12mo.)

4. A Continuation of the New Digester of Bones, &c.; sive continuatio novi Digestoris ossium autore Dionys. Papino, M.D., et Societatis Regiæ Socio. Londini, apud Joseph Streater. 1687. in 4to.

5. Recueil de diverses pièces touchant quelques nouvelles machines. Cassel, 1695. 12mo.

6. Fasciculus dissertationum de novis quibusdam machinis atque aliis argumentis philosoph. Marburgii Cottorum, 1695.

Small 8vo. Plates.—(A Translation of the 'Recueil;' see Brunet, Manuel des Libraires, 1843, v. PAPIN. M. Brunet, however, states that both the 'Recueil' and the 'Fasciculus' include the Treatise on 'La Manière d'amollir les Os;' from which we are led to imagine that this author, usually so accurate, has never had the advantage of seeing a copy of either the French or the Latin collection in question. We must confess ourselves to be similarly situated in regard to both of those rare, if not unique, works; the only information we possess as to their contents having been derived from the analyses of them given in the 'Philosophical Transactions' and the 'Acta Eruditorum.' See above, pp. 133-139.)

7. Nouvelle manière pour élever l'eau par la force du Feu, mise en lumière. Cassel, 1707. Small 8vo.

8. Ars nova ad aquam ignis adminiculo efficacissimè elevandam. Franc. 1707. 8vo.

2. *Papers by Papin, contained in the 'Philosophical Transactions.'*

1. Some experiments made in the Air-pump by Monsieur Papin, directed by Monsieur Hugens, (as appears in the Discourse printed at Paris, 1674). *Phil. Trans.*, vol. x., *for the year* 1675, p. 443-447.

2. A particular account, given by an anonymous French author, in his book of the Origin of Fountains, printed 1674, at Paris, to show that the rain and snow waters are sufficient to make Fountains and Rivers run perpetually. *Ibid.* p. 447-450.

3. Some experiments made in the Air-pump upon Plants; together with a way of taking exhausted Receivers away from off the said Engin: Tryed by the same Persons mention'd in Numb. 119, viz. Monsieur Hugens and M. Papin. *Ibid.* p. 477-481.

4. A continuation of the experiments made by Monsieur Hugens, and M. Papin, in the Air-Pump; which are about the preservation of bodies. *Ibid.* p. 492-495.

5. Some experiments touching animals, made in the Air-pump by the persons formerly mentioned, viz. Monsieur Hugens and M. Papin. *Ibid.* p. 542-543.

6. Promiscuous experiments made in the Air-pump likewise, by the same persons. *Ibid.* p. 544-548.

7. The description of a Siphon, performing the same things

with the Sipho Wurtemburgicus; invented by Dr. Papin, Fellow of the Royal Society. *Phil. Trans.* vol. xv., *for* 1685, p. 847-848.

8. A new way of raising water; by Dr. Papin, Fellow of the Royal Society. *Ibid.* p. 1093-1094.

9. Observations of Dr. Papin, Fellow of the Royal Society, on a French paper concerning a Perpetual Motion. *Ibid.* p. 1240-1241.

10. A full description, with the use, of the new contrivance for raising water, propounded in the Phil. Trans., No. 173; by Dr. Papin, Fellow of the R. S. *Ibid.* p. 1274-1278.

11. An account of an experiment, shown before the Royal Society, of shooting by the rarefaction of the air. By Dr. D. Papin, R.S.S. *Ibid.* vol. xvi. *for* 1686 *and* 1687, p. 21-22.

12. Some further remarks on the instrument proposed by an anonymous French author, for effecting a perpetual motion, an account whereof is given in No. 177 of these Transactions, by Dr. Papin, M.D., R.S.S. *Ibid.* p. 138-139.

13. A Demonstration of the Velocity wherewith the Air rushes into an exhausted receiver, lately produced before the R. Society, by Dr. D. Papin, Reg. Soc. S. *Ibid.* p. 193-195.

14. The answer of Dr. Papin to several objections made by Mr. Nuis against his engine for raising water by the rarefaction of the air, whereof a description is given in No. 178 of these Transactions. *Ibid.* p. 263-267.

15. An answer of the same to the author of the perpetual motion. *Ibid.* p. 267-268.

16. Account of a Book. A continuation of the new Digester of bones: It's improvements and new uses it hath been applyed to, both at Sea and Land. Together with some improvements and new uses of the Ayre Pump, tryed both in England and Italy. By D. Papin, M.D., Fellow of the Royal Society. *Ibid.* p. 329-332.

17. [Account of a Book.] Recueil de diverses Pieces touchant quelques nouvelles Machines, &c. Par Mr. D. Papin, Dr. en Med., &c. A Cassel, 1695. In 8vo. *Ibid.* vol. xix., *for* 1697, p. 483.

18. Part of a letter from Mr. D. Papin to Dr. Frederick Slare, Fellow of the College of Physicians and of the Royal Society, concerning an improvement of the Hessian bellows, &c. *Ibid.* vol. xxiv., *for* 1705, p. 1990-1992.

In the third and fourth volumes of Birch's 'History of the Royal 'Society'* there are recorded many experiments and observations communicated by Papin, as well as some details of the pecuniary aid, "convenient lodging in Gresham College," and further encouragement, which he received from the Society. From one of the earliest of those entries, (vol. iii. p. 486), it appears that on the 22nd of May, 1679, Papin was introduced by Mr. Hooke; and from one of the last of them, (vol. iv. p. 557), that "It was "ordered that Dr. Papin have a present of four copies of the "*History of Fishes*, and a letter testimonial, under the seal of the "Society, of the good services rendered them by him."

To one of Hooke's works, also, viz. his 'Lectures de Potentiâ 'Restitutivâ, or of Spring,' published in 1678, there is appended, among other 'Collections,' 'Dr. Papin's Letter, containing a 'Description of a Wind-Fountain, and his own particular contrivance about the forcer of its Syringe.'

3. *Papers by Papin, contained in the 'Acta Eruditorum Lipsiæ.'*

1. [Account of the] 'New Digester or Engine for softening 'bones,' &c., as published in England in 1681. 4to. *Act. Erud. for* 1682, p. 105.

2. [Account of] 'La manière d'amolir les os,' &c. Paris, 1682. 12mo. Translated from the English. *Ibid.* p. 305.

3. D. Papini Experimentum Societati Regiæ Anglicanæ exhibitum, concernens jaculationem mediante aëris rarefactione efficiendam. Ex Transact. Philos. M. Jan. et Febr. 1686, n. 179, p. 21. *Act. Erud. for* 1686, p. 500-501.

4. D. Papini, e Societate Regia Anglicana, inventa nova Hydragogica. Ex Transact. Philos. Anglic. Mens. Decemb. 1685, p. 1254 et 1274, seqq. *Ibid.* p. 545-551.

5. A Continuation of the New Digester of Bones, &c., sive Continuatio novi Digestoris Ossium, autore Dionys. Papino, M.D. et Societatis Regiæ Socio:—necnon Augmenta quædam et Expe-

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* 'The History of the Royal Society 'of London for improving of Natural 'Knowledge, from its first rise. In 'which the most considerable of those 'papers communicated to the Society, 'which have hitherto not been published, 'are inserted in their proper order, as a 'Supplement to the Philosophical Trans'actions. By Thomas Birch, D.D., Secre'tary to the Royal Society.' London, 1757, 4 vols. 4to.

rimenta nova circa Antliam Pneumaticam, facta partim in Anglia, partim in Italia, communicata a Dionys. Papino, Med. D. et Soc. Reg. Angl. Socio. Londini, apud Joseph Streater, 1687, in 4to.
Act. Erud. for 1687, pp. 276-284, *and* 325-335.

6. Demonstratio velocitatis qua cum aër irruit intra exhaustum recipiens. *Ibid.* 1688, p. 156-158.

7. Dionysii Papini, Mathematum in Academia Marpurgensi hoc tempore Professoris, Meletemata ad geminam Appendicem de Perpetuo Mobili Actis Eruditorum Lipsiensibus A. 1687, M. Jun. pag. 315 seqq. insertam. *Ibid.* p. 335-339.

8. Excerpta ex viri clarissimi, Dionysii Papini, Mathematum in Academia Marpurgensi Professoris publici, litteris ad . . . . de Novo Pulveris Pyrii usu. *Ibid.* p. 497-501.

9. Additamentum ad Disquisitionem Dn. Papini de novo pyrii pulveris usu, mense proximo Septembri in Actis hisce pag. 497, exhibitam: De usu tuborum prægrandium ad propagandam in longinquum vim motricem fluviorum, &c. Communicatum a laudato Dn. Papino. *Ibid.* p. 643-646.

10. Dionysii Papini Descriptio Torcularis, cujus in Actis Anni 1688, pag. 646, mentio facta fuit: Excerpta ex ejusdem litteris ad . . Marburgi d. 23 Dec. A. 1688, exaratis.
Ibid. 1689, p. 96-101.

11. D. Papini De gravitatis causa et proprietatibus observationes. *Ibid.* p. 183-188.

12. Ejusdem Examen machinæ Domini Perrault.
Ibid. p. 189-195.

13. Dion. Papini Rotatilis Suctor et pressor Hassiacus, in Serenissima aula Cassellana demonstratus et detectus.
Ibid. p. 317-322.

14. In J. B. Appendicem illam ad Perpetuum Mobile, Actis Novemb. A. 1688, pag. 592 sqq. insertam, Observationes D. P.
Ibid. p. 322-324.

15. Excerpta ex litteris Dn. Dion. Papini ad . . . de Instrumentis ad flammam sub aqua conservandam.
Ibid. p. 485-489.

16. Examen Siphonis Wurtemburgici in vertice effluentis. Excerpta ex Litteris Dn. Dion. Papin. ad . . . .
Ibid. 1690, p. 223-228.

17. Dion. Papini Nova Methodus ad vires motrices validissimas levi pretio comparandas. *Act. Erud. for* 1690, p. 410-414.

18. Mechanicorum de viribus motricibus sententia, asserta a Dn. Papino adversus Cl. G. G. L. objectiones. *Ibid.* 1691, p. 6-13.

19. Dion. Papini observationes quædam circa materias ad Hydraulicam spectantes, Mensi Februario hujus anni insertas. *Ibid.* p. 208-213.

20. [Account of] Fasciculus Dissertationum de novis quibusdam machinis atque aliis argumentis philosophicis. Autore Dionysio Papino, Med. Doct. Matheseos Prof. Publ. Marpurgensi. Marpurgi, 1695, in 8, plagg. 20, cum tribus plagg. figurarum.

No. II.

HISTORICAL NOTE ON THE DISCOVERY OF THE THEORY OF THE COMPOSITION OF WATER. BY THE RIGHT HON. HENRY LORD BROUGHAM, F.R.S., AND MEMBER OF THE NATIONAL INSTITUTE OF FRANCE.

THERE can be no doubt whatever, that the experiment of Mr. Warltire, related in Dr. Priestley's 5th volume,* gave rise to this

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* Mr. Warltire's letter is dated Birmingham, 18th April, 1781, and was published by Dr. Priestley in the Appendix to the 2nd Vol. of his 'Experiments and Observations relating to various branches of Natural Philosophy; with a continuation of the Observations on Air,'—forming, in fact, the 5th volume of his 'Experiments and Observations on different kinds of Air;' printed at Birmingham in 1781.

Mr. Warltire's first experiments were made in a copper ball or flask, which held three wine pints, the weight 14 oz.; and his object was to determine "whether heat is heavy or not." After stating his mode of mixing the airs, and of adjusting the balance, he says, he "always accurately balanced the flask of common air, then found the difference of weight after the inflammable air was introduced, that he might be certain he had confined the proper proportion of each. The electric spark having passed through them, the flask became hot, and was cooled by exposing it to the common air of the room: it was then hung up again to the balance, and a loss of weight was always found, but not constantly the same; upon an average it was two grains."

He goes on to say, "I have fired air in glass vessels since I saw you (Dr. Priestley) venture to do it, and I have observed, *as you did*, that, though the glass was clean and dry before, yet, after firing the air, it became dewy, and was lined with a sooty substance."

As you are upon a nice balancing of claims, ought not Dr. Priestley to have the credit of first noticing the dew?

In some remarks which follow, by Dr. Priestley, he confirms the loss of weight, and adds, "I do not think, however, that so very bold an opinion as that of the latent heat of bodies contributing to inquiry, at least in England; Mr. Cavendish expressly refers to it, as having set him upon making his experiments.—(Phil. Trans. 1784, p. 126.) The experiment of Mr. Warltire consisted in firing, by electricity, a mixture of inflammable and common air in a close vessel, and two things were said to be observed: *first*, a sensible loss of weight; *second*, a dewy deposit on the sides of the vessel.

Mr. Watt, in a note to p. 332 of his paper, Phil. Trans. 1784, inadvertently states, that the dewy deposit was first observed by Mr. Cavendish; but Mr. Cavendish himself, p. 127, expressly states Mr. Warltire to have observed it, and cites Dr. Priestley's 5th volume.

Mr. Cavendish himself could find no loss of weight, and he says that Dr. Priestley had also tried the experiment, and found none. But Mr. Cavendish found there was always a dewy deposit, without any sooty matter. The result of many trials was, that common air and inflammable air being burnt together, in the proportion of 1000 measures of the former to 423 of the latter, "about "one-fifth of the common air, and nearly all the inflammable air, "lose their elasticity, and *are condensed into the dew* which lines "the glass." He examined the dew, and found it to be pure water. He therefore concludes, that "almost all the inflammable air, and about one-sixth of the common air, are turned "into pure water."

Mr. Cavendish then burned, in the same way, dephlogisticated and inflammable airs, (oxygen and hydrogen gases), and the deposit was always more or less acidulous, accordingly as the air burnt with the inflammable air was more or less phlogisticated. The acid was found to be nitrous. Mr. Cavendish states, that "almost the whole of the inflammable and dephlogisticated air "*is converted into pure water*." And, again, that "if these airs "could be obtained perfectly pure, the whole would be con"densed." And he accounts for common air and inflammable air, when burnt together, not producing acid, by supposing that

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" their weight, should be received without " more experiments, and made upon a still " larger scale. If it be confirmed, it will " no doubt be thought to be a fact of a " very remarkable nature, and will do the " greatest honour to the sagacity of Mr. " Warltire. I must add, that the moment " he saw the moisture on the inside of the " close glass vessel in which I afterwards " fired the inflammable air, he said, that " it confirmed an opinion he had long " entertained, viz. that common air de" posits its moisture when it is phlogisti" cated."

It seems evident, that neither Mr. Warltire, nor Dr. Priestley, attributed the dew to anything else than a mechanical deposit of the moisture suspended in common air.—[NOTE BY MR. JAMES WATT, JUN.]

the heat produced is not sufficient. He then says that these experiments, with the exception of what relates to the acid, were made in the summer of 1781, and mentioned to Dr. Priestley; and adds, that "a friend of his, (Mr. Cavendish's), last summer," (that is, 1783), "gave some account of them to Mr. Lavoisier, "as well as of the conclusion drawn from them, that dephlo-"gisticated air is only water deprived of its phlogiston; but, "at that time, so far was Mr. Lavoisier from thinking any such "opinion warranted, that till he was prevailed upon to repeat "the experiment himself, he found some difficulty in believing "that nearly the whole of the two airs could be converted into "water." The friend is known to have been Dr., afterwards Sir Charles Blagden; and it is a remarkable circumstance, that this passage of Mr. Cavendish's paper appears not to have been in it when originally presented to the Royal Society; for the paper is apparently in Mr. Cavendish's hand, and the paragraph, pp. 134, 135, is not found in it, but is added to it, and directed to be inserted in that place. It is, moreover, not in Mr. Cavendish's hand, but in Sir Charles Blagden's; and, indeed, the latter must have given him the information as to Mr. Lavoisier, with whom it is not said that Mr. Cavendish had any correspondence. The paper itself was read 15th January, 1784. The volume was published about six months afterwards.

Mr. Lavoisier's memoir, (in the Mém. de l'Académie des Sciences for 1781), had been read partly in November and December, 1783, and additions were afterwards made to it. It was published in 1784. It contained Mr. Lavoisier's account of his experiments in June, 1783, at which, he says, Sir Charles Blagden was present; and it states that he told Mr. Lavoisier of Mr. Cavendish having "already burnt inflammable air in close "vessels, and obtained a very sensible quantity of water." But he, Mr. Lavoisier, says nothing of Sir Charles Blagden having also mentioned Mr. Cavendish's conclusion from the experiment. He expressly states, that the weight of the water was equal to that of the two airs burnt, unless the heat and light which escape are ponderable, which he holds them not to be. His account, therefore, is not reconcilable with Sir Charles Blagden's, and the latter was most probably written as a contradiction of it, after Mr. Cavendish's paper had been read, and when the Mémoires of the Académie were received in this country. These Mémoires were published in 1784, and could not, certainly, have arrived, when Mr. Cavendish's paper was written, nor when it was read to the Royal Society.

But it is further to be remarked, that this passage of Mr. Cavendish's paper in Sir Charles Blagden's handwriting, only mentions the experiments having been communicated to Dr. Priestley; "they were made," says the passage, "in 1781, and communicated to Dr. Priestley;" it is not said when, nor is it said that "the conclusions drawn from them," and which Sir Charles Blagden says he communicated to Mr. Lavoisier in summer 1783, were ever communicated to Dr. Priestley; and Dr. Priestley, in his paper, (referred to in Mr. Cavendish's), which was read June, 1783, and written before April of that year, says nothing of Mr. Cavendish's theory, though he mentions his experiment.

Several propositions then are proved by this statement.

First, That Mr. Cavendish, in his paper, read 15th January, 1784, relates the capital experiment of burning oxygen and hydrogen gases in a close vessel, and finding pure water to be the produce of the combustion.

Secondly, That, in the same paper, he drew from this experiment the conclusion, that the two gases were converted or turned into water.

Thirdly, That Sir Charles Blagden inserted in the same paper, with Mr. Cavendish's consent, a statement that the experiment had first been made by Mr. Cavendish in summer 1781, and mentioned to Dr. Priestley, though it is not said when, nor is it said that any conclusion was mentioned to Dr. Priestley, nor is it said at what time Mr. Cavendish first drew that conclusion. *A most material omission.*

Fourthly, That in the addition made to the paper by Sir Charles Blagden, the conclusion of Mr. Cavendish is stated to be, that oxygen gas is water deprived of phlogiston; this addition having been made after Mr. Lavoisier's memoir arrived in England.

It may further be observed, that in another addition to the paper, which is in Mr. Cavendish's handwriting, and which was certainly made after Mr. Lavoisier's memoir had arrived, Mr. Cavendish for the first time distinctly states, as upon Mr. Lavoisier's hypothesis, that water consists of hydrogen united to oxygen gas. There is no substantial difference, perhaps, between this and the conclusion stated to have been drawn by Mr. Cavendish himself, that oxygen gas is water deprived of phlogiston, supposing phlogiston to be synonymous with hydrogen; but the former proposition is certainly the more distinct and unequivocal of the two; and it is to be observed that Mr. Cavendish, in the original part of the paper, *i. e.* the part read January, 1784, before the arrival of Lavoisier's, considers it more just to hold inflammable air to be phlogisticated water than pure phlogiston, (p. 140).

We are now to see what Mr. Watt did; and the dates here become very material. It appears that he wrote a letter to Dr. Priestley on 26th April, 1783, in which he reasons on the experiment of burning the two gases in a close vessel, and draws the conclusion, "that water is composed of dephlogisticated air and "phlogiston, deprived of part of their latent heat."* The letter was received by Dr. Priestley and delivered to Sir Joseph Banks with a request that it might be read to the Royal Society; but Mr. Watt afterwards desired this to be delayed, in order that he might examine some new experiments of Dr. Priestley, so that it was not read until the 22nd April, 1784. In the interval between the delivery of this letter to Dr. Priestley, and the reading of it, Mr. Watt had addressed another letter to Mr. De Luc, dated 26th November, 1783,† with many further observations and reasonings, but almost the whole of the original letter is preserved in this, and is distinguished by inverted commas. One of the passages thus marked, is that which has the important conclusion above mentioned; and that letter is stated, in the subsequent one, to have been communicated to several members of the Royal Society at the time of its reaching Dr. Priestley, viz. April, 1783.

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* It may with certainty be concluded from Mr. Watt's private and unpublished letters, of which the copies taken by his copying-machine, then recently invented, are preserved, that his theory of the composition of water was already formed in December, 1782, and probably much earlier. Dr. Priestley, in his paper of 21st April, 1783, p. 416, states, that Mr. Watt, prior to his (the Doctor's) experiments, had entertained the idea of the possibility of the conversion of water or steam into permanent air. And Mr. Watt himself, in his paper, Phil. Trans. p. 335, asserts, that for many years he had entertained the opinion that air was a modification of water, and he enters at some length into the facts and reasoning upon which that deduction was founded.—[NOTE BY MR. JAMES WATT, JUN.]

† The letter was addressed to Mr. J. A. De Luc, the well-known Genevese philosopher, then a Fellow of the Royal Society, and Reader to Queen Charlotte. He was the friend of Mr. Watt, who did not then belong to the Society. Mr. De Luc, following the motions of the Court, was not always in London, and seldom attended the meetings of the Royal Society. He was not present when Mr. Cavendish's paper of 15th January, 1784, was read; but, hearing of it from Dr. Blagden, he obtained a loan of it from Mr. Cavendish, and writes to Mr. Watt on the 1st March following, to apprize him of it, adding that he has perused it, and promising an analysis. In the postscript he states, "In short, they expound and prove "your system, word for word, and say "nothing of you." The promised analysis is given in another letter of the 4th of the same month. Mr. Watt replies on the 6th, with all the feelings which a conviction he had been ill-treated was calculated to inspire, and makes use of those vivid expressions which M. Arago has quoted; he states his intention of being in London in the ensuing week, and his opinion, that the reading of his letter to the Royal Society will be the proper step to be taken. He accordingly went there, waited upon the President of the Royal Society, Sir Joseph Banks, was received with all the courtesy and just feeling which distinguished that most honourable man; and it was settled that both the letter to Dr. Priestley of 26th April, 1783, and that to Mr. De Luc of 26th November, 1783, should be successively read. The former was done on the 22nd, and the latter on the 29th April, 1784.—[NOTE BY MR. JAMES WATT, JUN.]

In Mr. Cavendish's paper as at first read, no allusion is to be found to Mr. Watt's theory. But in an addition made also in Sir C. Blagden's hand, after Mr. Watt's paper had been read, there is a reference to that theory, (Phil. Trans. 1784, p. 140), and Mr. Cavendish's reasons are given for not encumbering his theory with that part of Mr. Watt's which regards the evolution of latent heat. It is thus left somewhat doubtful, whether Mr. Cavendish had ever seen the letter of April, 1783, or whether he had seen only the paper (of 26th November, 1783) of which that letter formed a part, and which was read 29th April, 1784. That the first letter was for some time, (two months, as appears from the papers of Mr. Watt), in the hands of Sir Joseph Banks, and other members of the Society, during the preceding Spring, is certain, from the statements in the note to p. 330; and that Sir Charles Blagden, the Secretary, should not have seen it, seems impossible; for Sir Joseph Banks must have delivered it to him at the time when it was intended to be read at one of the Society's meetings, (Phil. Trans. p. 330, Note); and, as the letter itself remains among the Society's Records, in the same volume with the paper into which the greater part of it was introduced, it must have been in the custody of Sir C. Blagden. It is equally difficult to suppose, that the person who wrote the remarkable passage already referred to, respecting Mr. Cavendish's conclusions having been communicated to Mr. Lavoisier in the summer of 1783, (that is, in June), should not have mentioned to Mr. Cavendish that Mr. Watt had drawn the same conclusion in the Spring of 1783, (that is, in April at the latest). For the conclusions are identical, with the single difference, that Mr. Cavendish calls dephlogisticated air, water deprived of its phlogiston, and Mr. Watt says, that water is composed of dephlogisticated air and phlogiston.

We may remark, there is the same uncertainty or vagueness introduced into Mr. Watt's theory, which we before observed in Mr. Cavendish's, by the use of the term Phlogiston, without exactly defining it.* Mr. Cavendish leaves it uncertain, whether or not he meant by phlogiston simply inflammable air, and he inclines rather to call inflammable air, water united to phlogiston. Mr. Watt says expressly, even in his later paper, (of November, 1783), and in a passage not to be found in the letter of April, 1783, that he thinks that inflammable air contains a small quantity of water, and much elementary heat. It must be admitted that such expressions as these on the part of both of those great men, betoken a certain hesitation respecting the theory of the composition of water. If they had ever formed to themselves the idea, that water is a compound of the two gases deprived of their latent heat,—that is, of the two gases,—with the same distinctiveness which marks Mr. Lavoisier's statement of the theory, such obscurity and uncertainty would have been avoided.*

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* Mr. Watt, in a note to his paper of 26th November, 1783, p. 331, observes, "previous to Dr. Priestley's making these "experiments, Mr. Kirwan had proved, "by very ingenious deductions from other "facts, that inflammable air was, in all "probability, the real phlogiston in an "aërial form. These arguments were "perfectly convincing to me, but it seems "proper to rest that part of the argument "on direct experiment."—[NOTE BY MR. JAMES WATT, JUN.]

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* Mr. Watt, in his letter of 26th April, 1783, thus expresses his theory and conclusions, (Phil. Trans. p. 333):—" Let " us now consider what obviously happens " in the case of the deflagration of the " inflammable and dephlogisticated air. " These two kinds of air unite with " violence, they become red-hot, and, " upon cooling, totally disappear. When " the vessel is cooled, a quantity of water " is found in it, equal to the weight of " the air employed. This water is then the " only remaining product of the process, " and *water*, *light*, and *heat*, are all the " products," (unless, he adds in the paper of November, there be some other matter set free, which escapes our senses). " *Are* " *we not then authorised to conclude, that* " *water is composed of dephlogisticated* " *air and phlogiston, deprived of their* " *latent or elementary heat; that dephlogisticated or pure air is composed* " *of water deprived of its phlogiston, and* " *united to elementary heat and light;* " *that the latter are contained in it in a* " *latent state, so as not to be sensible to* " *the thermometer or to the eye; and if* " *light be only a modification of heat, or* " *a circumstance attending it, or a component part of the inflammable air, then* " *pure or dephlogisticated air is composed* " *of water deprived of its phlogiston, and* " *united to elementary heat?*"

Is not this as clear, precise, and intelligible, as the conclusions of Mr. Lavoisier?—[NOTE BY MR. JAMES WATT, JUN.]

The obscurity with which Lord Brougham charges the theoretical conceptions of Watt and Cavendish, does not appear to me well-founded. In 1784 the preparation of two permanent and very dissimilar gases was known. Some called these gases, pure air, and inflammable air; others, dephlogisticated air and phlogiston; and lastly, others, oxygen and hydrogen. By combining dephlogisticated air and phlogiston, water was produced equal in weight to that of the two gases. Water thenceforward was no longer a simple body, but a compound of dephlogisticated air and of phlogiston. The chemist who drew that conclusion might have erroneous ideas as to the intimate nature of phlogiston, without that throwing any uncertainty upon the merit of his first discovery. Even at this day, have we *mathematically demonstrated* that hydrogen (or phlogiston) is an elementary body; or that it is not, as Watt and Cavendish supposed at the time, the combination of a radical and of a little water?—[NOTE BY M. ARAGO.]

It should be borne in mind that the new chemical nomenclature was not proposed to the Academy of Sciences by the Messrs. De Morveau, Lavoisier, Berthollet, and De Fourcroy, until 1787, accompanied by introductory memoirs by M. Lavoisier and M. De Morveau.

Lavoisier himself had suggested the use of the term *acidifying principle* or *oxygen*, in 1778, for the basis of pure or dephlogisticated air; and he used it in subsequent memoirs in 1780 and 1782; but it was not until the decomposition of water was discovered in 1783 and 1784, that he fully adopted it. Berthollet, perhaps the most philosophical chemist of France, did not become a convert to this nomenclature

Several further propositions may now be stated, as the result of the facts regarding Mr. Watt.

First, That there is no evidence of any person having reduced the theory of composition to writing, in a shape which now remains, so early as Mr. Watt.

Secondly, That he states the theory, both in April and November, 1783, in language somewhat more distinctly referring to composition, than Mr. Cavendish does in 1784, and that his reference to the evolution of latent heat renders it more distinct than Mr. Cavendish's.

Thirdly, That there is no proof, nor even any assertion, of Mr. Cavendish's theory, (what Sir C. Blagden calls his conclusion), having been communicated to Dr. Priestley before Mr. Watt stated his theory in 1783, still less of Mr. Watt having heard of it, while his whole letter shows that he never had been aware of it, either from Dr. Priestley, or from any other quarter.

Fourthly, That Mr. Watt's theory was well known among the members of the Society, some months before Mr. Cavendish's statement appears to have been reduced into writing, and eight months before it was presented to the Society. We may, indeed, go farther, and affirm, as another deduction from the facts and dates, that, as far as the evidence goes, there is proof of Mr. Watt having first drawn the conclusion; at least, that no proof exists of any one having drawn it so early as he is proved to have done.

Lastly, That a reluctance to give up the doctrine of phlogiston, a kind of timidity on the score of that long-established and deeply-rooted opinion, prevented both Mr. Watt and Mr. Cavendish from doing full justice to their own theory; while Mr. Lavoisier, who had entirely shaken off these trammels, first presented the new doctrine in its entire perfection and consistency.*

All three may have made the important step nearly at the same time, and unknown to each other; the step, namely, of concluding

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until 1785, nor did De Morveau and Fourcroy, according to the statement of the latter, fully enter into it until the end of 1786. As far as we recollect, it was first legitimated, if we may use the expression, in Lavoisier's System of Chemistry in 1789. It is surely, then, wrong to expect that Mr. Watt, in expounding his theory in 1783, should use a phraseology not generally sanctioned in France until four years later, not admitted by Black, Priestley, Kirwan, and other great English chemists, until a still more recent period, and by some of them never recognised at all.—[NOTE BY MR. JAMES WATT, JUN.]

* It could scarcely be expected that Mr. Watt, writing and publishing for the first time, amid the distractions of a large manufacturing concern, and of extensive commercial affairs, could compete with the eloquent and practised pen of so great a writer as Lavoisier; but it seems to me, who am certainly no impartial judge, that the summing-up of his theory, (p. 333 of his paper), here quoted, p. 331, is equally luminous and well expressed as are the conclusions of the illustrious French chemist. —[NOTE BY MR. JAMES WATT, JUN.]

from the experiment, that the two gases entered into combination, and that water was the result; for this, with more or less of distinctness, is the inference which all three drew.

But there is the statement of Sir Charles Blagden, to show that Mr. Lavoisier had heard of Mr. Cavendish's drawing this inference before his (Mr. Lavoisier's) capital experiment was made;* and it appears that Mr. Lavoisier, after Sir C. Blagden's statement had been embodied in Mr. Cavendish's paper and made public, never gave any contradiction to it in any of his subsequent memoirs which are to be found in the Mémoires de l'Académie, though his own account of that experiment, and of what then passed, is inconsistent with Sir Charles Blagden's statement.†

But there is not any assertion at all, even from Sir C. Blagden, zealous for Mr. Cavendish's priority as he was, that Mr. Watt had ever heard of Mr. Cavendish's theory before he formed his own.

Whether or not Mr. Cavendish had heard of Mr. Watt's theory previous to drawing his conclusions, appears more doubtful. The supposition that he had so heard, rests on the improbability of his, (Sir Charles Blagden's), and many others knowing what Mr. Watt had done, and not communicating it to Mr. Cavendish, and on the omission of any assertion in Mr. Cavendish's paper, even in the part written by Sir C. Blagden with the view of claiming priority as against Mr. Lavoisier, that Mr. Cavendish had drawn his conclusion before April, 1783, although in one of the additions to that paper, reference is made to Mr. Watt's theory.

As great obscurity hangs over the material question at what time Mr. Cavendish first drew the conclusion from his experiment, it may be as well to examine what that great man's habit was in communicating his discoveries to the Royal Society.

A Committee of the Royal Society, with Mr. Gilpin the clerk, made a series of experiments on the formation of nitrous acid, under Mr. Cavendish's direction, and to satisfy those who had doubted his theory of its composition, first given accidentally in the paper of January, 1784, and afterwards more fully in another paper, June, 1785. Those experiments occupied from the 6th December, 1787, to 19th March, 1788, and Mr. Cavendish's paper upon them was read 17th April, 1788. It was, therefore, written and printed within a month of the experiments being concluded.

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* In the letter which Sir Charles Blagden addressed to Professor Crell, and which appeared in Crell's *Annalen* for 1786, professing to give a detailed history of the discovery, he says expressly, that he had communicated to Lavoisier the conclusions both of Cavendish *and Watt*. This last name appears in that letter for the first time in the recital of the verbal communications of the Secretary of the Royal Society, and is never mentioned by Lavoisier.—[NOTE BY MR. JAMES WATT, JUN.]

† Could Blagden's letter to Crell also have escaped Lavoisier's notice?—[NOTE BY MR. JAMES WATT, JUN.]

Mr. Kirwan answered Mr. Cavendish's paper (of 15th January, 1784) on water, in one which was read 5th February, 1784, and Mr. Cavendish replied in a paper read 4th March, 1784.

Mr. Cavendish's experiments on the density of the earth were made from the 5th August, 1797, to the 27th May, 1798. The paper upon that subject was read 27th June, 1798.

The account of the eudiometer was communicated at apparently a greater interval; at least the only time mentioned in the account of the experiments is the latter half of 1781, and the paper was read January, 1783. It is, however, probable from the nature of the subject, that he made further trials during the year 1782.

That Mr. Watt formed his theory during the few months or weeks immediately preceding April, 1783, seems probable.* It is certain that he considered the theory as his own, and makes no reference to any previous communication from any one upon the subject, nor of having ever heard of Mr. Cavendish drawing the same conclusion.

The improbability must also be admitted to be extreme, of Sir Charles Blagden ever having heard of Mr. Cavendish's theory prior to the date of Mr. Watt's letter, and not mentioning that circumstance in the insertion which he made in Mr. Cavendish's paper.

It deserves to be farther mentioned, that Mr. Watt left the correction of the press, and everything relating to the publishing of his paper, to Sir Charles Blagden. A letter remains from him, to that effect, written to Sir Charles Blagden, and Mr. Watt never saw the paper until it was printed.†

Since M. Arago's learned 'Eloge' was published, with this paper as an Appendix, the Rev. W. Vernon Harcourt has entered into controversy with us both, or, I should rather say, with M. Arago, for he has kindly spared me; and while I acknowledge my obligations for this courtesy of my reverend, learned, and valued friend, I must express my unqualified admiration of his boldness in singling out for his antagonist my illustrious colleague, rather than the far weaker combatant against whom he might so much more safely have done battle. Whatever might have been his fate had he taken the more prudent course, I must fairly say, (even without waiting until my fellow champion seal our adversary's doom), that I have seldom seen any two parties more unequally matched, or any disputation in which the victory was so complete. The attack on M. Arago might have passed well enough at a popular meeting at Birmingham, before which it was spoken; but as a scientific inquirer, it would be a flattery running the risk of seeming ironical to weigh the reverend author against the most eminent philosopher of the day; although upon a question of evidence, (which this really is, as well as a scientific discussion), I might be content to succumb before him. As a strange notion, however, seems to pervade this paper, that everything depends on the character of Mr. Cavendish, it may be as well to repeat the disclaimer already very distinctly made of all intention to cast the slightest doubt upon that great man's perfect good faith in the whole affair; I never having supposed that he borrowed from Mr. Watt, though M. Arago, Professor Robison,* and Sir H. Davy, as well as myself, have always been convinced that Mr. Watt had, unknown to him, anticipated his great discovery. It is also said by Mr. Harcourt that the late Dr. Henry having examined Mr. Watt's manuscripts, decided against his priority. I have Dr. H.'s letter before me of June, 1820, stating most clearly, most fully, and most directly, the reverse, and deciding in Mr. Watt's favour. I must add, having read the full publication with fac-similes, Mr. Harcourt has now clearly proved one thing, and it is really of some importance. He has made it appear that in all Mr. Cavendish's diaries and notes of his experiments, not an intimation occurs of the composition of water having been inferred by him from those experiments earlier than Mr. Watt's paper of Spring, 1783.

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* That the idea existed in his mind previously, is proved by his declarations to Dr. Priestley, cited by the latter; by his own assertions, p. 335 of his paper; and by the existing copies of his letters in December, 1782.—[NOTE BY MR. JAMES WATT, JUN.]

† The notes of Mr. James Watt formed part of the manuscript transmitted to me by Lord Brougham; and it is at the express desire of my illustrious fellow-member, that I have printed them, as a useful commentary upon his essay.—[NOTE BY M. ARAGO.]

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* Encyc. Brit., vol. xviii. p. 808. This able and learned article enters at length into the proofs of Mr. Watt's claims, and it was published in 1797, thirteen years before Mr. Cavendish's death.

No. III.

SUMMARY OF THE HISTORY OF THE PROGRESS TOWARDS THE DISCOVERY OF THE COMPOSITION OF WATER, AND OF THE DISCOVERY ITSELF.

1776.

Volta fires inflammable air by the electric spark.

1776-77.

Macquer explodes mixtures of inflammable and common airs, and of inflammable and dephlogisticated airs, (but not by the electric spark), in glass vessels, not close. He makes his observation of the moisture formed when inflammable air is burned in common air, and of that moisture being pure water.

1778.

Macquer publishes his observations.

1781.

Before the 18th of April, Mr. Warltire, being encouraged by Dr. Priestley, fires, by the electric spark, a mixture of common and inflammable air in a close metal flask, weighing the vessel before and after the explosion, observing the dewy deposit, and finding only a very trifling loss of weight.

Dr. Priestley fires mixtures of common and inflammable airs, and of inflammable and dephlogisticated airs, in a close *glass* vessel, and observes a deposit of water on the sides of the vessel.

Mr. Warltire repeats Dr. Priestley's experiment in the close glass vessel, and confirms his observation of the dewy deposit.

In July, after the publication of Dr. Priestley's and Mr. Warltire's experiments, Mr. Cavendish repeats them.

No conclusion as to the real origin of the water, published by Mr. Cavendish; nor communicated to any individual, nor contained in the Journal and Notes of his experiments; nor alleged by himself, nor by any one else, to have been then drawn by him.

1782.

13th December.—Mr. Watt, in writing to Mr. De Luc and Dr. Black, mentions an opinion which he had held for many years, that air was a modification of water; and that if all the latent heat of steam could be turned into sensible heat, the constitution of the steam would be essentially changed, and it would become air.

1783.

"Dr. Priestley having put dry dephlogisticated air and dry
" inflammable air into a close [glass] vessel, and kindled them by
" the electric spark, finds on the sides of the vessel a quantity of
" water equal in weight to the air employed."

26th March.—Mr. Watt mentions as new to him, that experiment of Dr. Priestley's.

21st April.—Mr. Watt states in his letters, both to Dr. Priestley and to Dr. Black, his conclusions, viz.: "that water is composed " of dephlogisticated and inflammable air, or phlogiston, deprived " of part of their latent heat; and that dephlogisticated or pure " air is composed of water deprived of its phlogiston, and united " to heat and light." He requests his letter to Dr. Priestley to be read to the Royal Society.

26th April.—Mr. Watt having re-written his letter of the 21st, sends it to Dr. Priestley, who receives it in London,—shows it to several members of the Royal Society,—*among whom was Mr. Cavendish's intimate friend and private assistant, Dr. Blagden*,—and then delivers it to Sir Joseph Banks the President, for the purpose of being publicly read to the Society.

Prior to the 23rd of June, Mr. Watt requests the public reading of his paper to be delayed till he should examine new experiments, said by Dr. Priestley to contradict his theory.

24th June.—MM. Lavoisier and La Place perform their experiment at Paris, at which Blagden is present. They are informed, as Lavoisier says, of Mr. Cavendish having burned the two airs and obtained water;—as Blagden subsequently says, of the conclusions of Watt and Cavendish;—(this being the first time that any conclusion of Mr. Cavendish on the subject is referred to by any one.)

25th June.—MM. Lavoisier and La Place give an account of their experiment to the Academy of Sciences, and Lavoisier states the conclusion as to the compound nature of water, to have been drawn by La Place and himself.

June and July.—M. Monge performs his experiments at Mézières; and repeats them in October.

Martinmas.—M. Lavoisier reads to the Academy of Sciences his memoir on the composition of water.

26th November.—Mr. Watt being fully satisfied of the correctness of his theory, and hearing that Lavoisier was passing it off as his own, repeats it in his letter to Mr. De Luc, which he requests may be read to the Royal Society.

No conclusion published, nor known to have been committed to writing, nor alleged, (excepting by Dr. Blagden), to have been drawn, by Mr. Cavendish.

1784.

15th January.—In his paper read to the Royal Society this day, Mr. Cavendish, *for the first time*, states publicly in writing, and in his own person, his conclusions as to the compound nature of water; coinciding generally with those of Mr. Watt, but omitting the consideration of latent heat, as well as the mention of Mr. Watt's name.

March.—Mr. Watt, finding that in Mr. Cavendish's paper his own theory had been fully explained and proved, and his name excluded, expresses his indignation, and takes immediate steps for having his own letters, of 26th April and 26th November, 1783, read at the Royal Society, with their true dates.

21st April.—MM. Meusnier and Lavoisier read to the Academy of Sciences their memoir on the decomposition of water, which is printed in the same year.

22nd April.—Mr. Watt's first letter, which had till now remained in the custody of the President, is, according to his request, read at the Royal Society.

29th April.—Mr. Watt's second letter is also read. Both letters are ordered to be printed in the Philosophical Transactions.

5th May.—Dr. Blagden is appointed Secretary to the Royal Society, and is entrusted with the superintendence of the printing of both of Mr. Watt's letters, to be embodied in one paper, with marks distinguishing each from the other.

June ?—M. Lavoisier's memoir is printed with additions.

July ?—Mr. Cavendish's paper is printed;—the separate copies, *with the erroneous date of* 1783 *instead of* 1784 on their titlepage; *with the correct date*, 1784, *omitted from the heading of the paper;* and the paper itself containing two interpolations, made by Dr. Blagden some months after it had been read to the Society. In one of these, Mr. Watt's name is *for the first time* mentioned as if by Mr. Cavendish, and his theory alluded to as his own.

August.—Mr. Watt's paper is printed, under the *sole* superintendence of Dr. Blagden, *and with the erroneous date of* 1784 *instead of* 1783.

1786.

The paper of M. Monge is published; no date being mentioned at which it had been read.

J. P. M.

END OF THE APPENDIX.

From the Medal by Pidgeon,
Struck at the Royal Mint in 1829
Reverse

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